

# Premise Plumbing Modeling Workshop

April 22, 2020

## Organizing Committee

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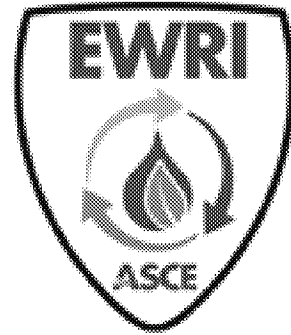
William Platten, USEPA,  
[Platten.William@epa.gov](mailto:Platten.William@epa.gov)

# Agenda

- 10:00 AM - Introduction
  - Welcome – Regan Murray
  - History and Workshop Objectives – Juneseok Lee
  - Moderator – Jon Burkhardt
- 10:15 AM - Premise Plumbing Modeling
  - Modeling Premise Plumbing with a 2D Model – Tom Walski
- 10:28 AM - Demand and Hydraulic Modeling
  - Demand Modeling – Mirjam Blokker
- 10:41 AM - Water Quality Issues
  - Water Quality Issues in Building Water Systems – Michele Prevost
- 10:54 AM - Design and Regulation Issues
  - Increase Customer Satisfaction by Improving the Performance of Premise Plumbing Systems – Gary Klein
- 11:07 AM - Future Direction and Needs
  - Vision for an EPANET for Premise Plumbing Modeling – Walter Grayman
- 11:20 AM - Participant Survey – Steve Buchberger
- 11:33 AM - Feedback and Q/A – Jon Burkhardt
- 11:50 AM - What's Next? – Regan Murray

# Welcome

# Environmental & Water Resources Institute

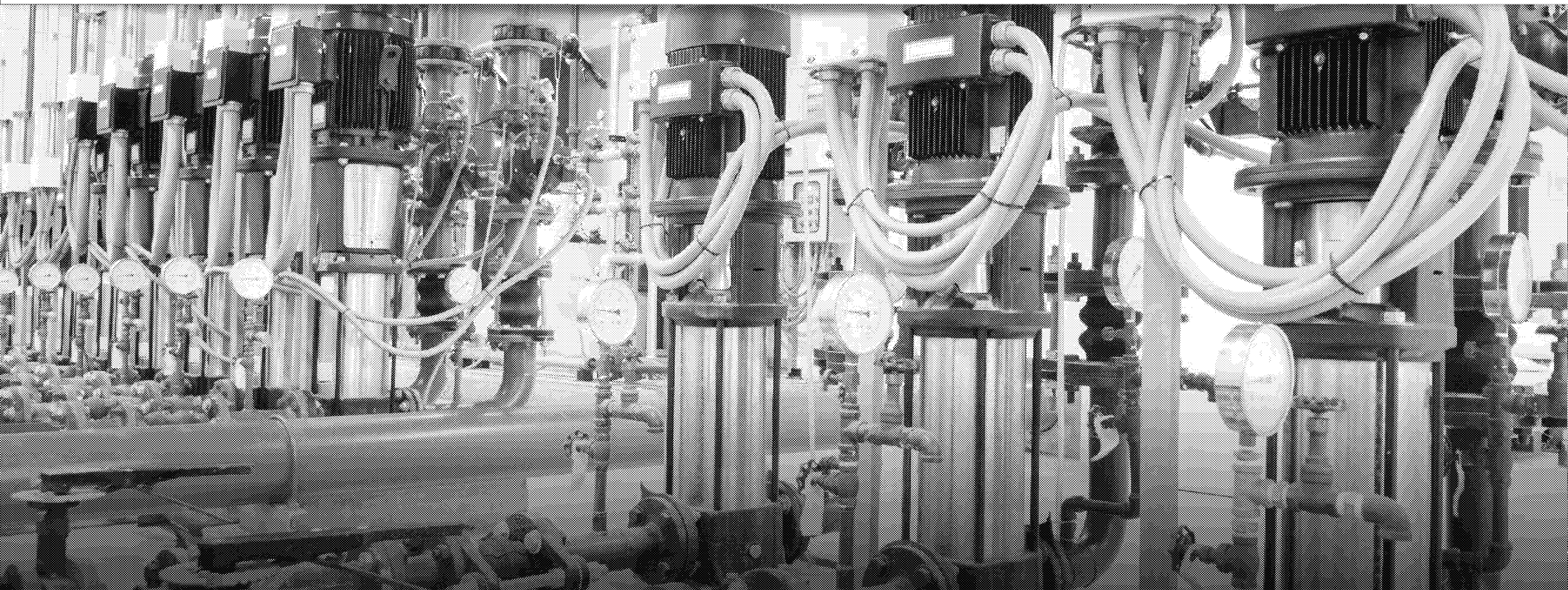


- **EWRI** is the American Society of Civil Engineers' (ASCE) technical arm for environmental and water-related issues.
- There are approximately 25,000 members of EWRI.

# Premise Plumbing Modeling (PPM) Task Committee

- **PPM** is a task committee of the Water Distribution System Analysis Committee. It has the lead in EWRI in advancing the area of premise plumbing modeling.
- **Purpose:** advance the science of the new field of premise plumbing modeling and to help develop building water systems management tools for use by practicing engineers, as well as the larger water distribution research community in support of the safe design and operation of water distribution systems.





# MODELING PREMISE PLUMBING WITH A 2D MODEL

Tom Walski

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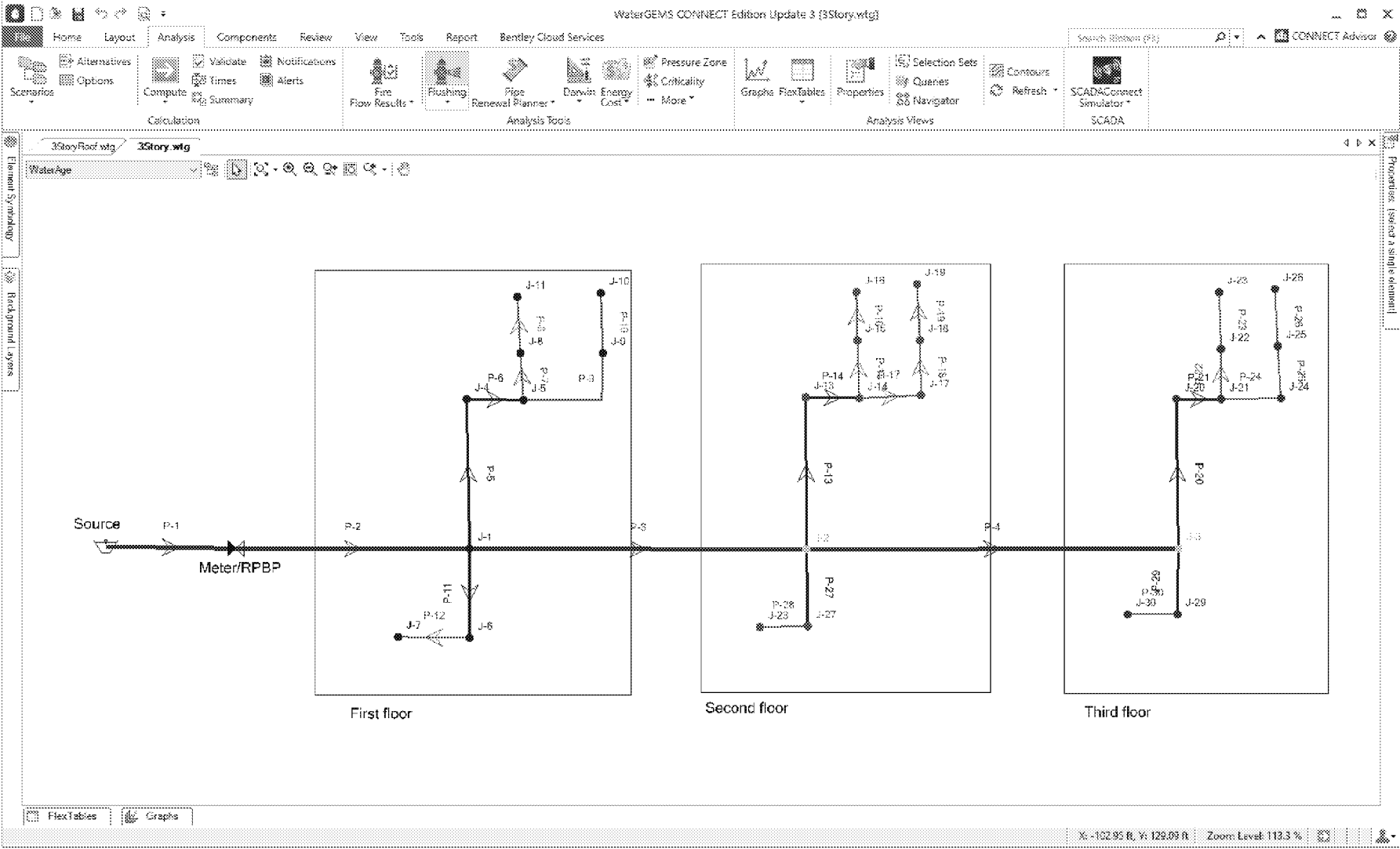
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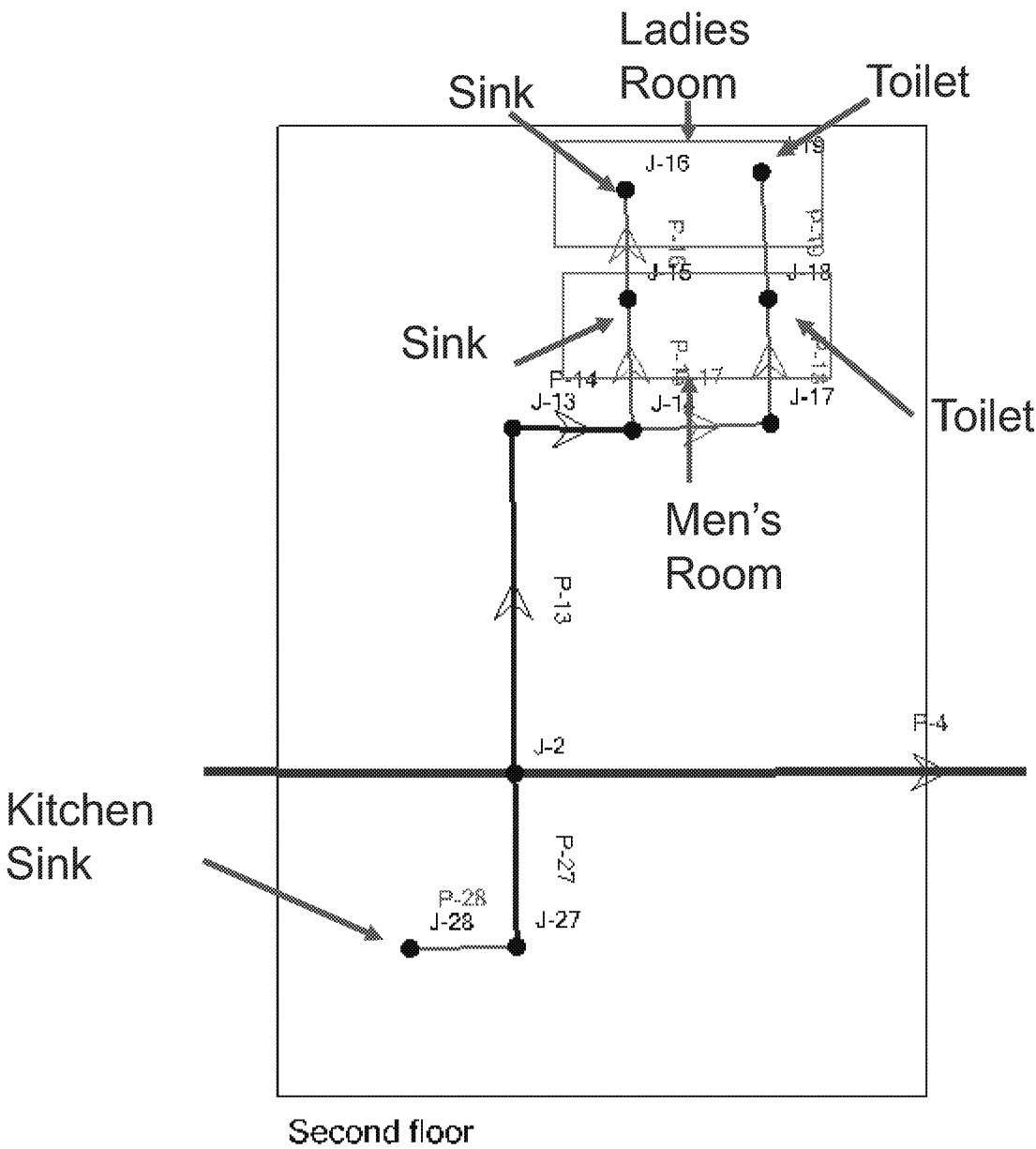
# Overview

- 2D water distribution modeling standard
- Hydraulics/water quality same in buildings
- Elevation data (no DEM)
- Pulse type water use (not smooth patterns)
- Results display (3D/4D)

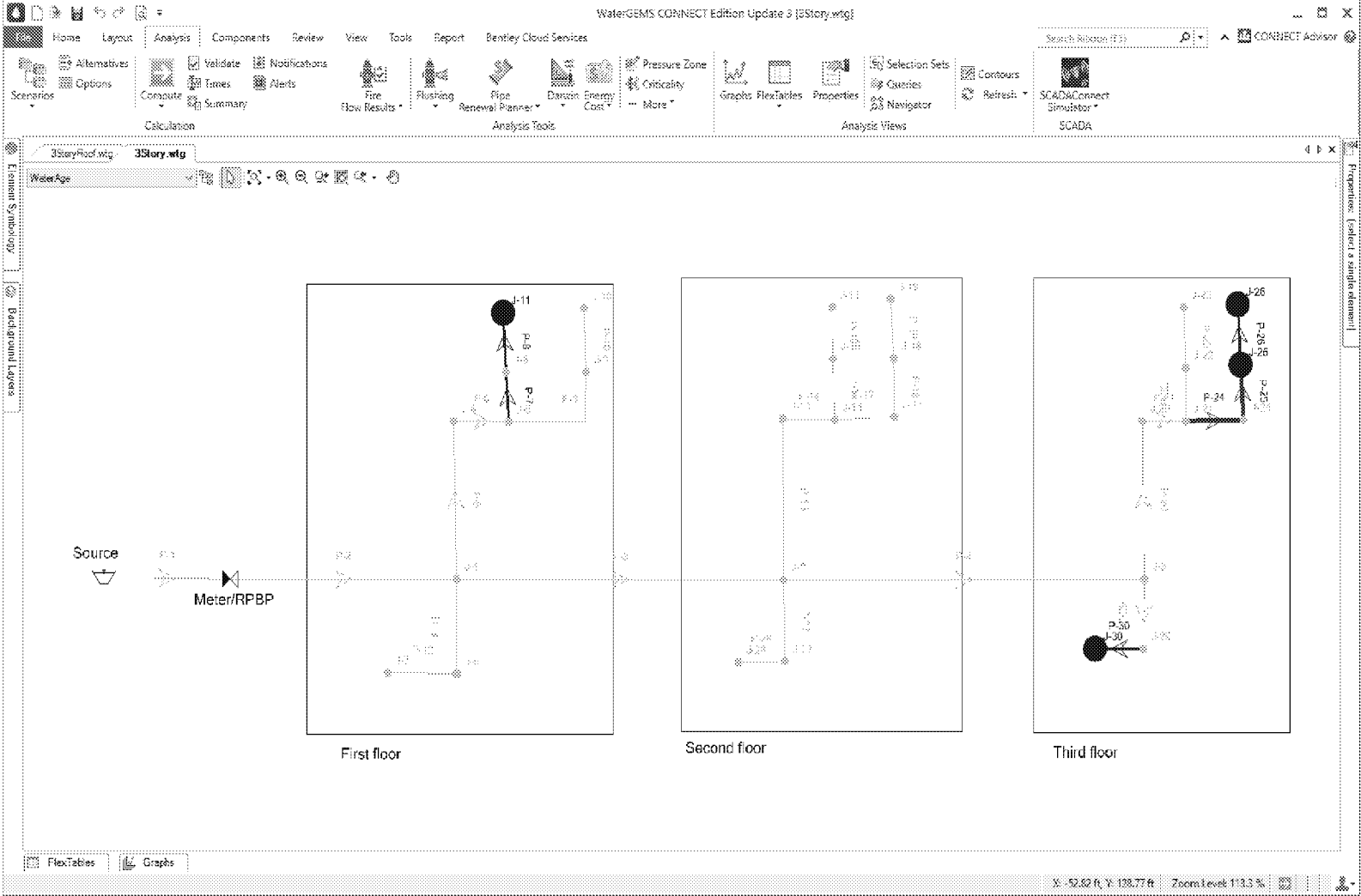
# Build WaterGEMS Model Manually



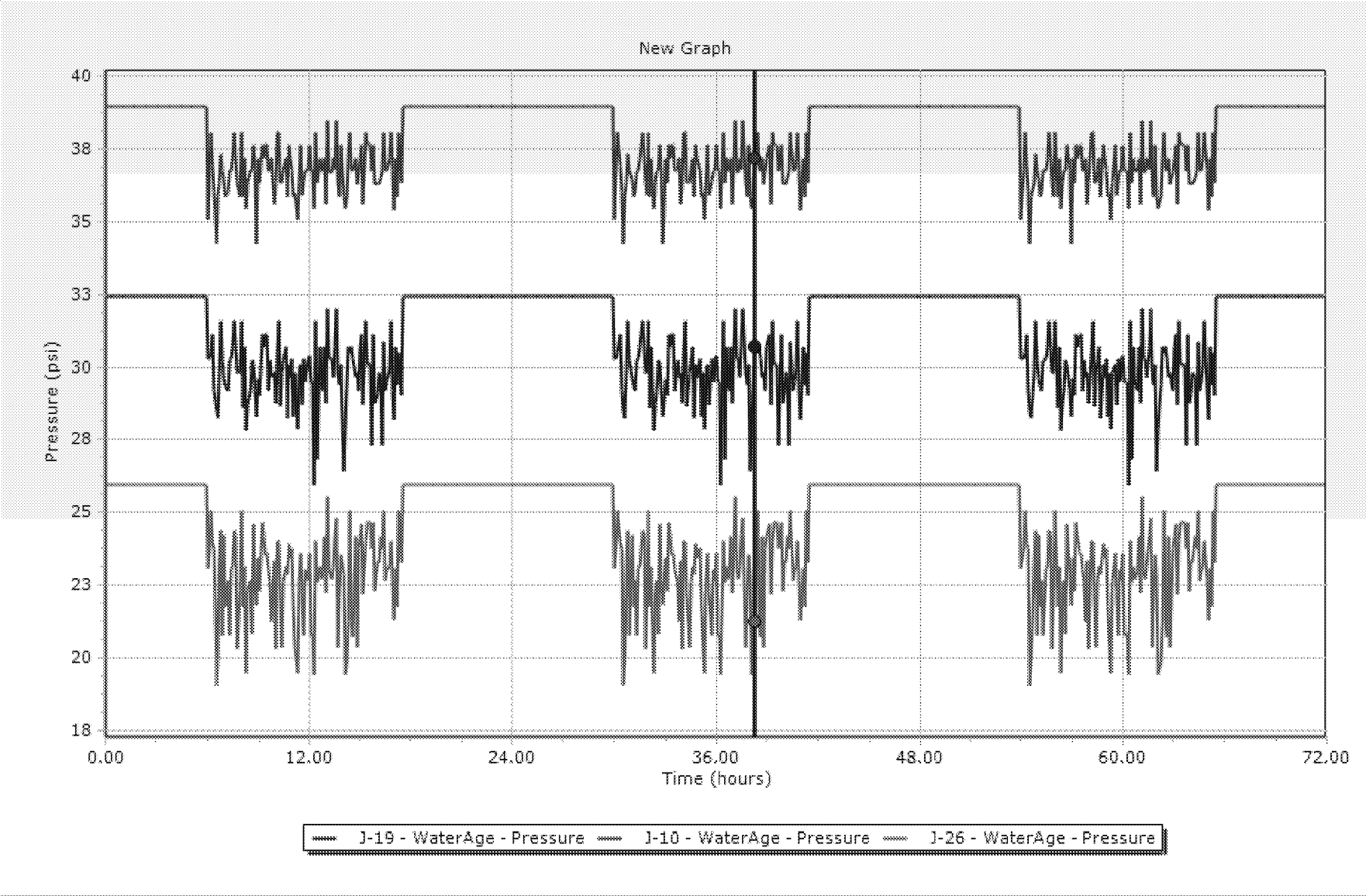
# Individual Floor



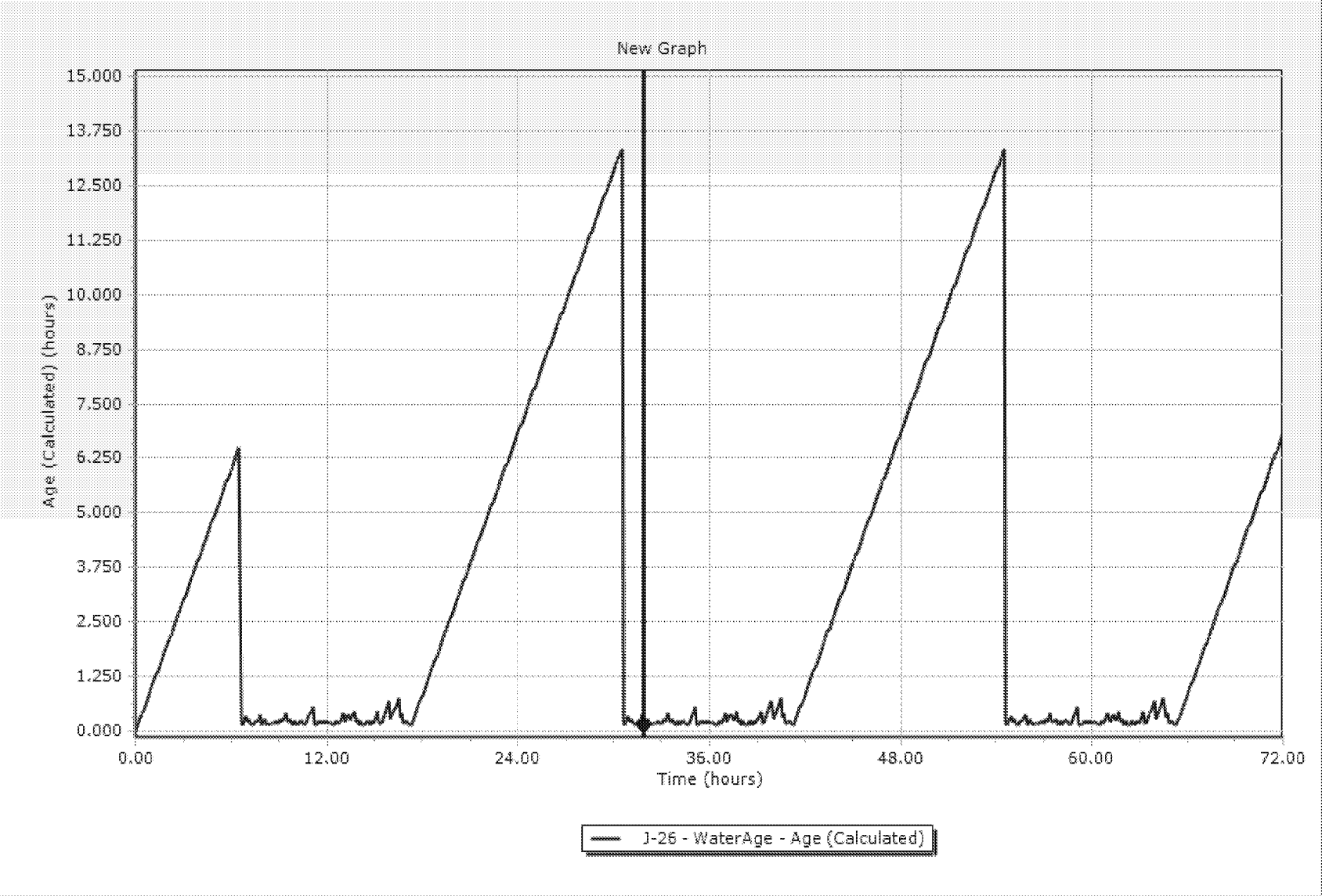
# Result Display



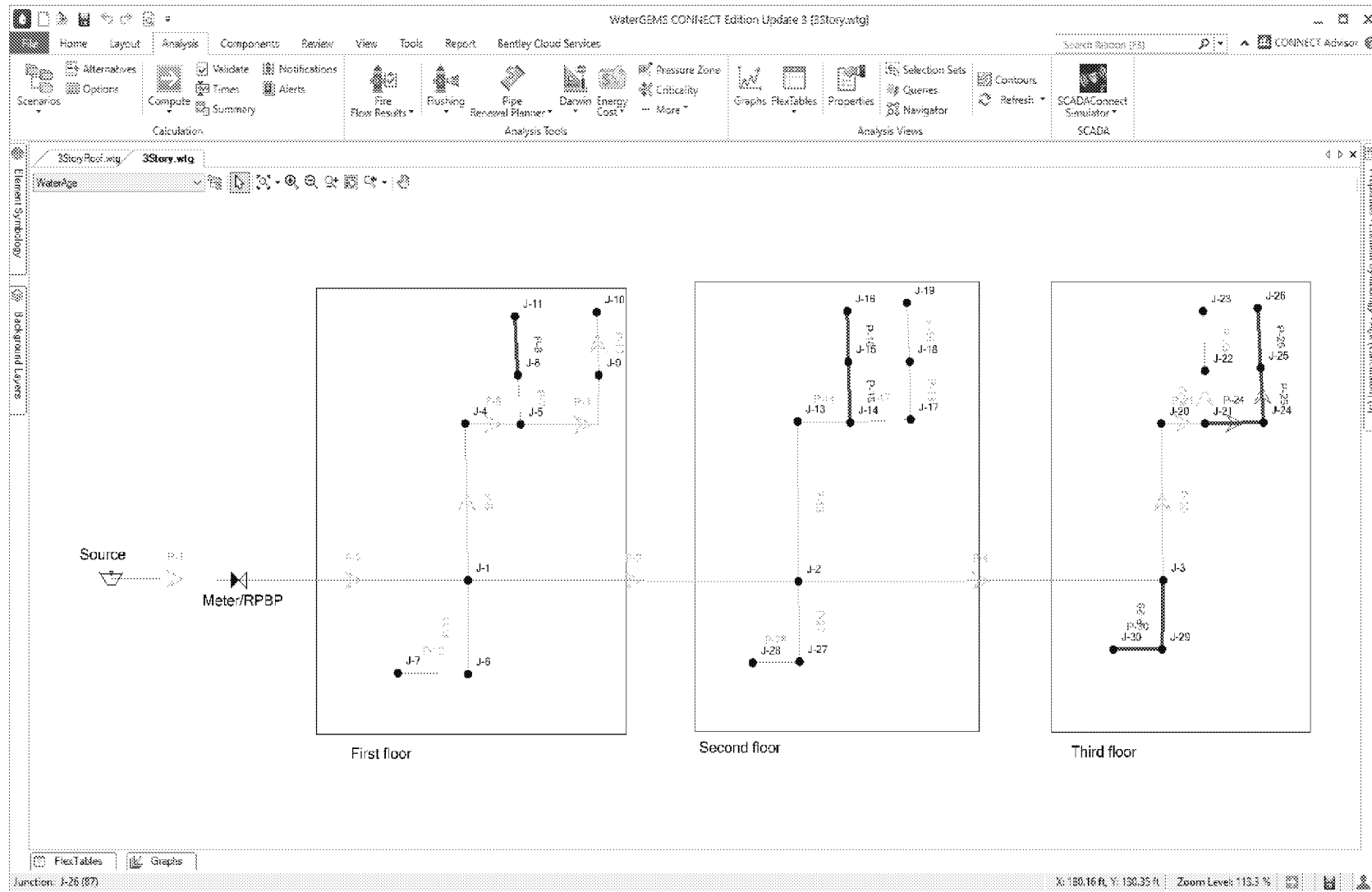
# Pressure Fluctuations



# Water Age (Top Floor)

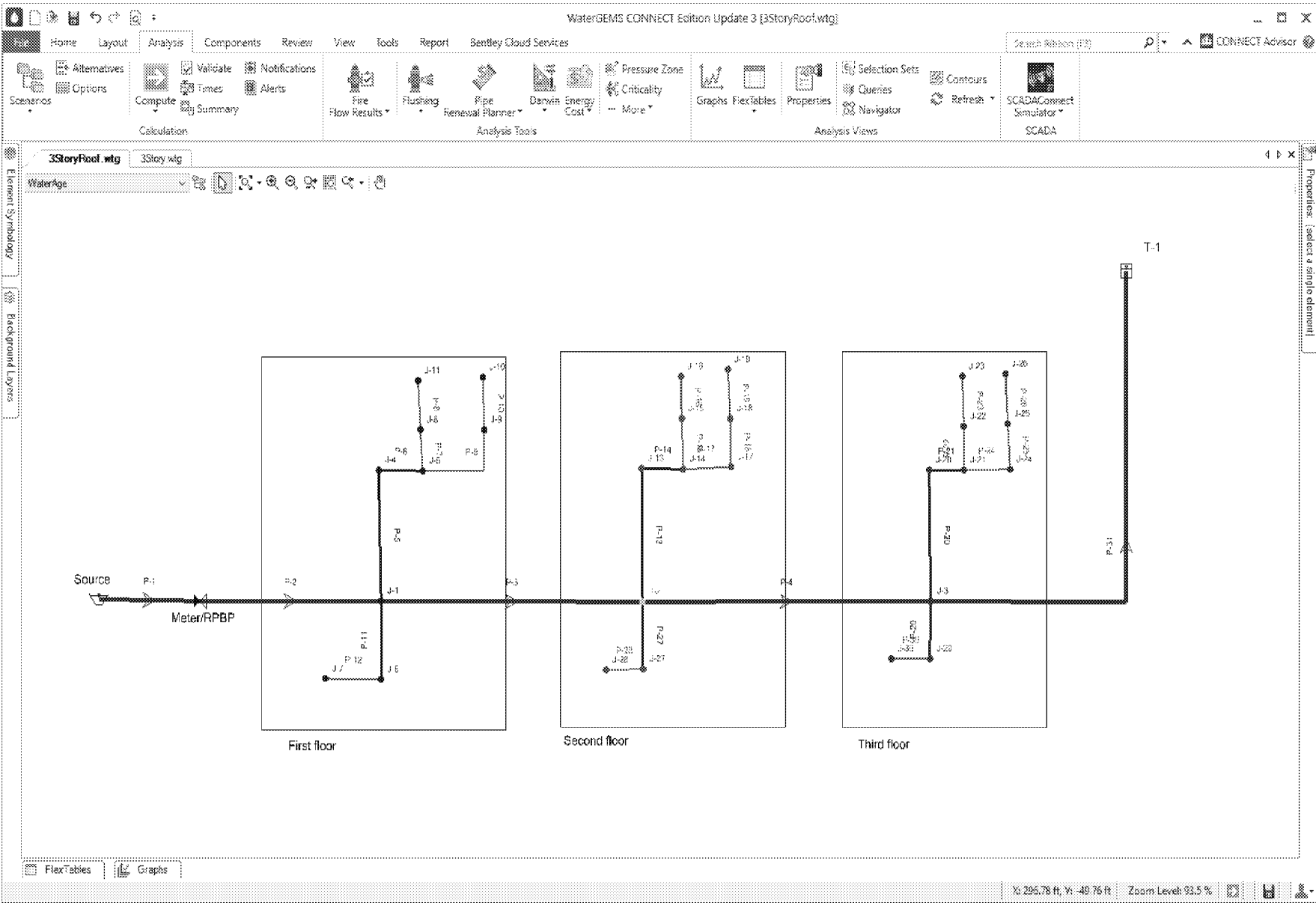


# Water Age (early morning)

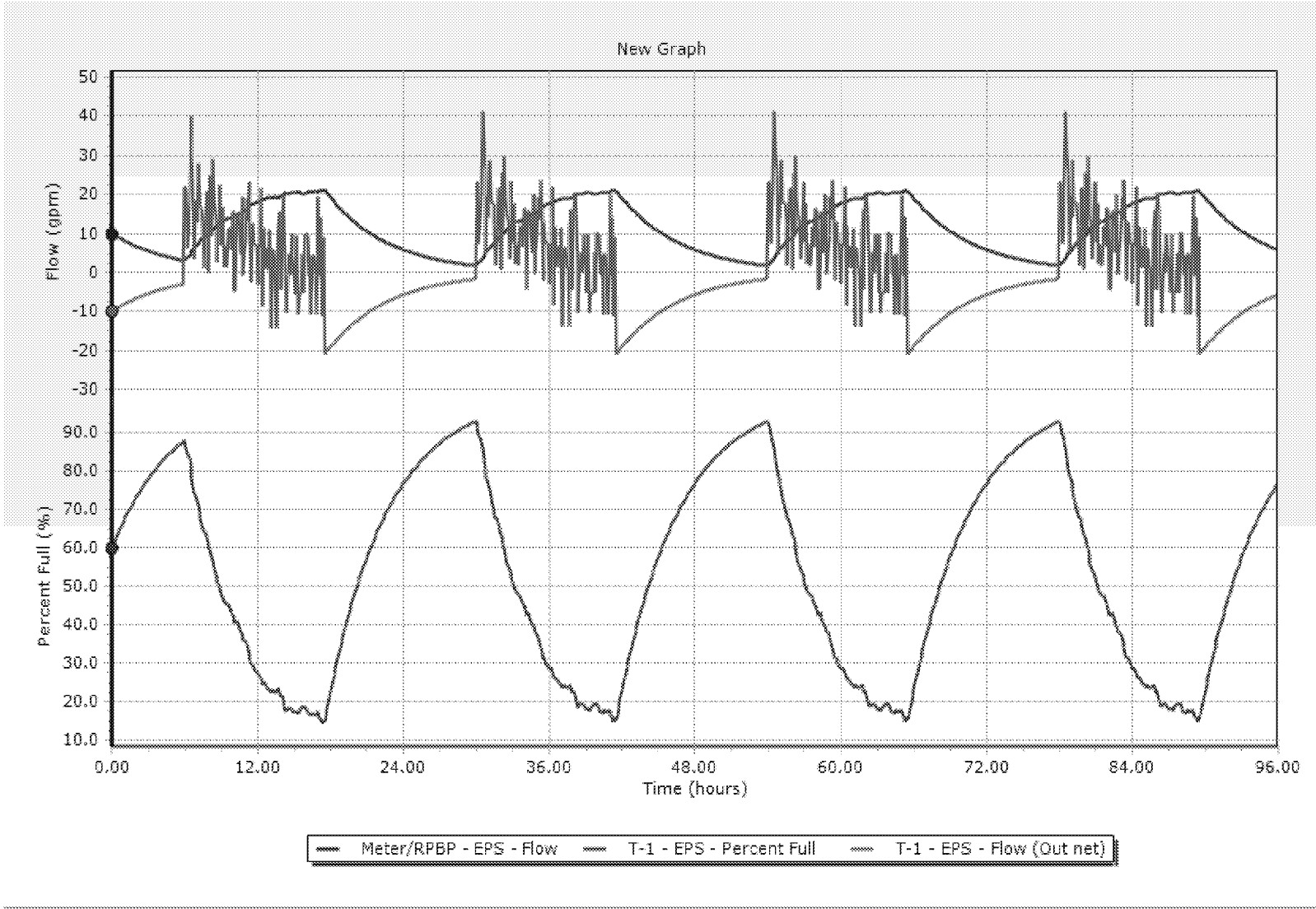


# Rooftop Tank

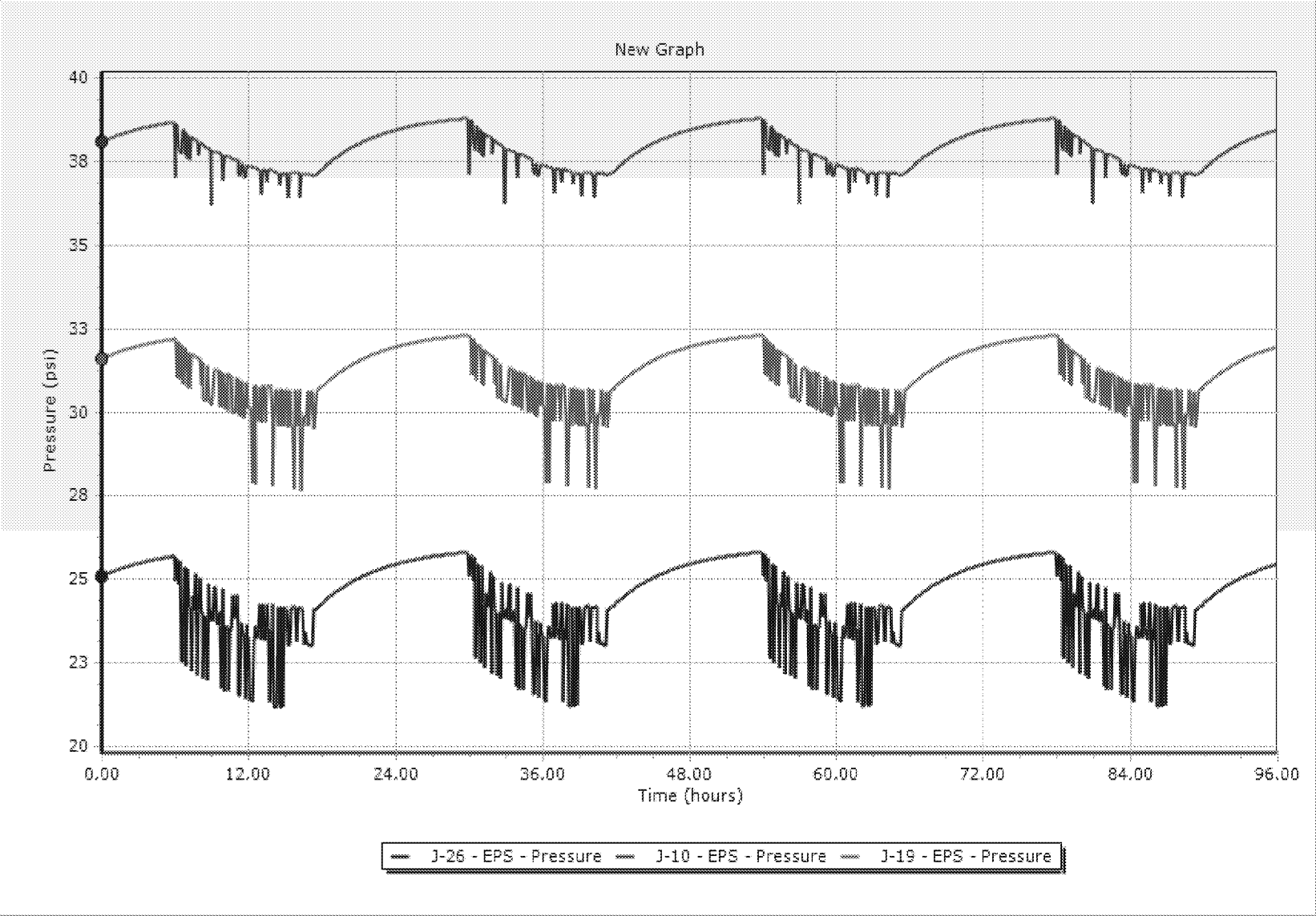
7,500 gal  
1/2 day



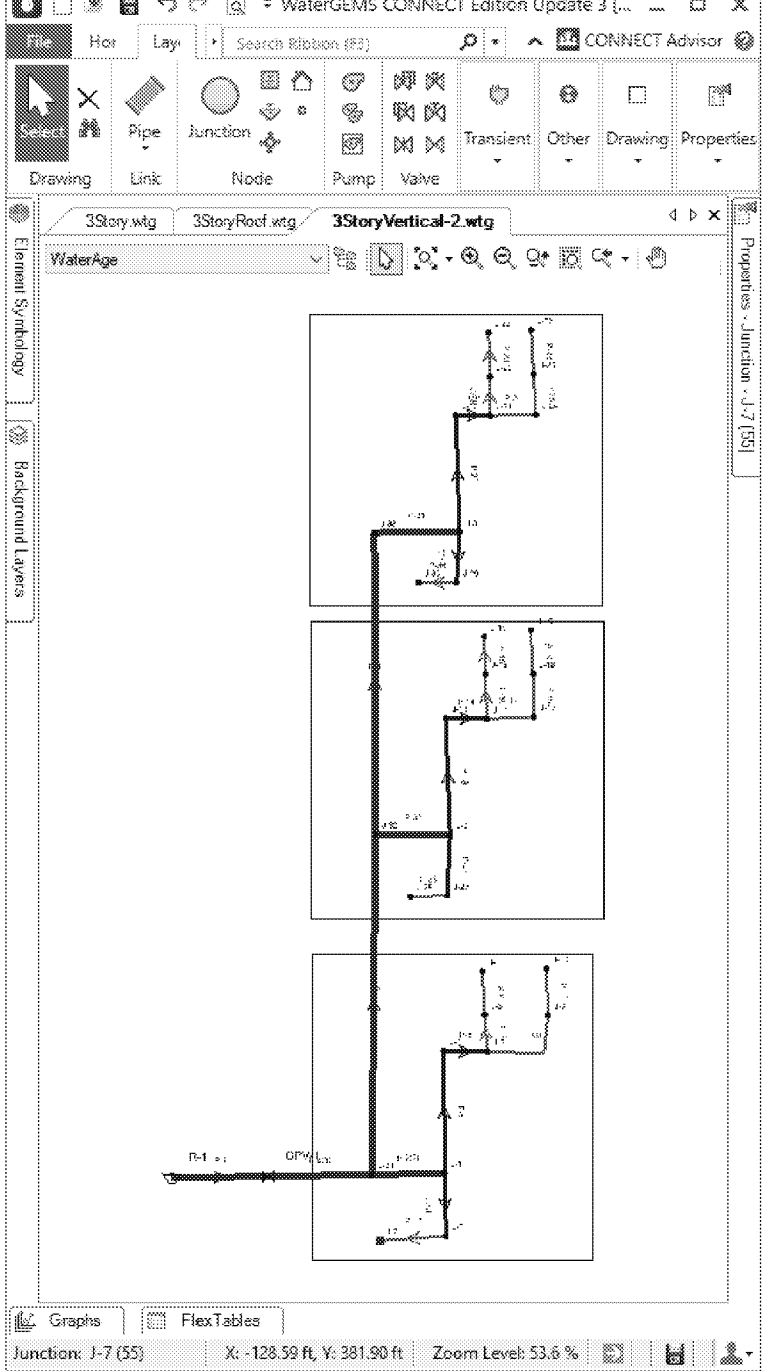
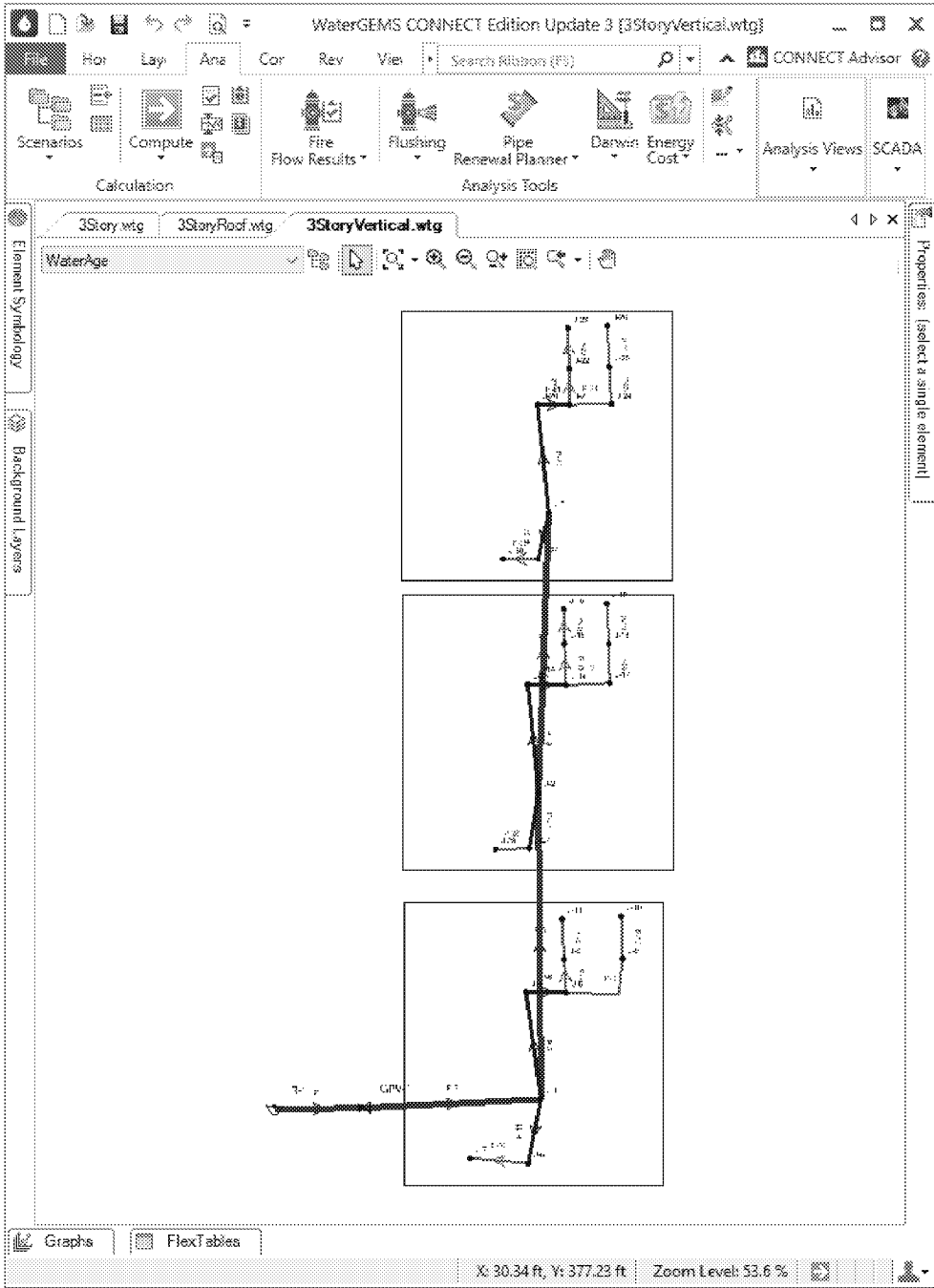
# Storage Behavior



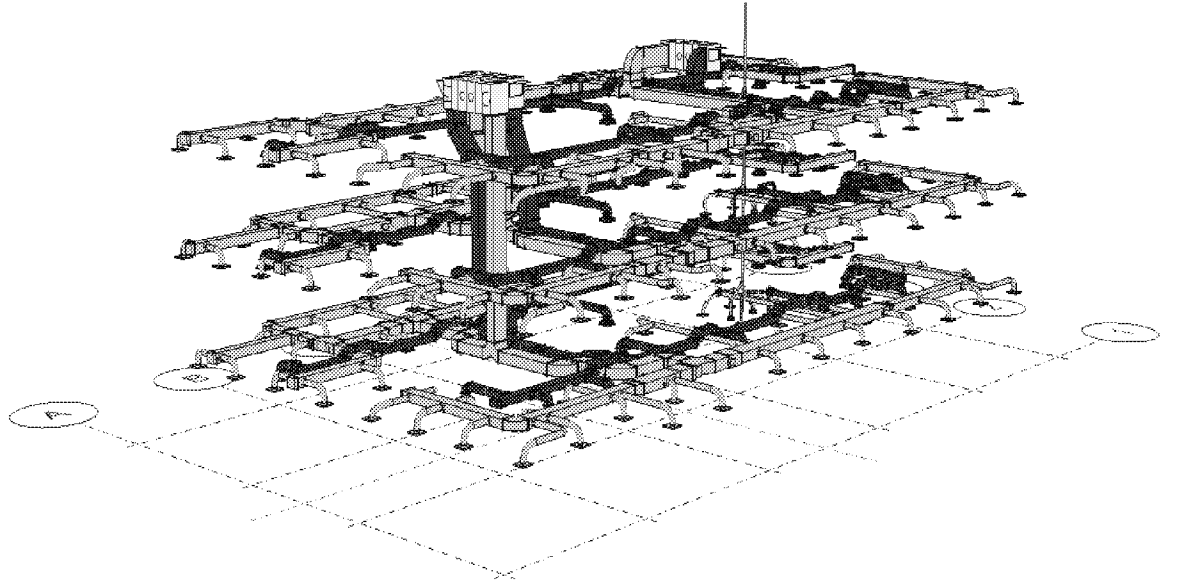
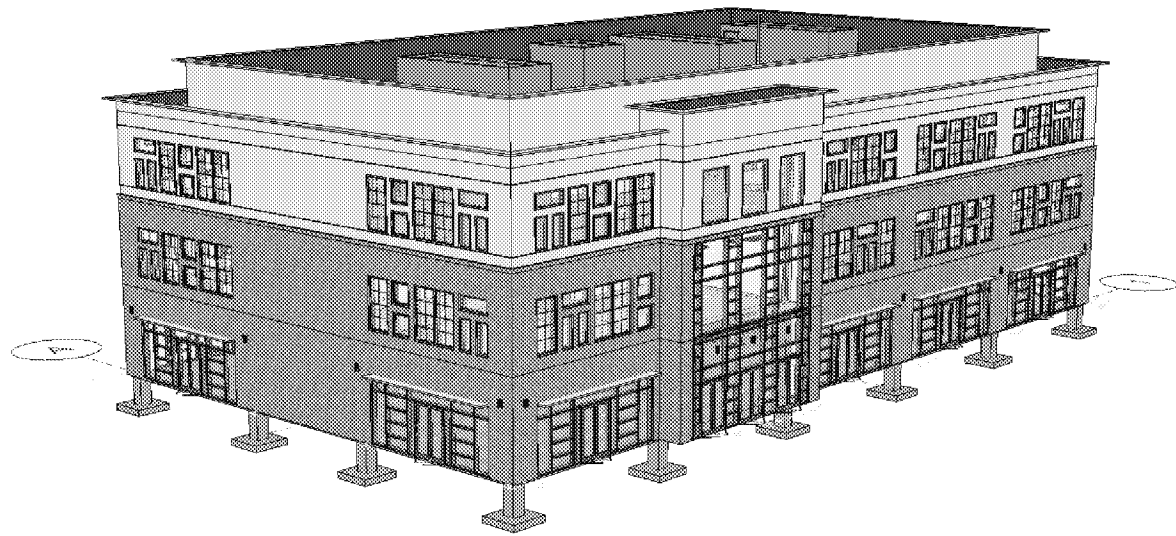
# Pressure with tank



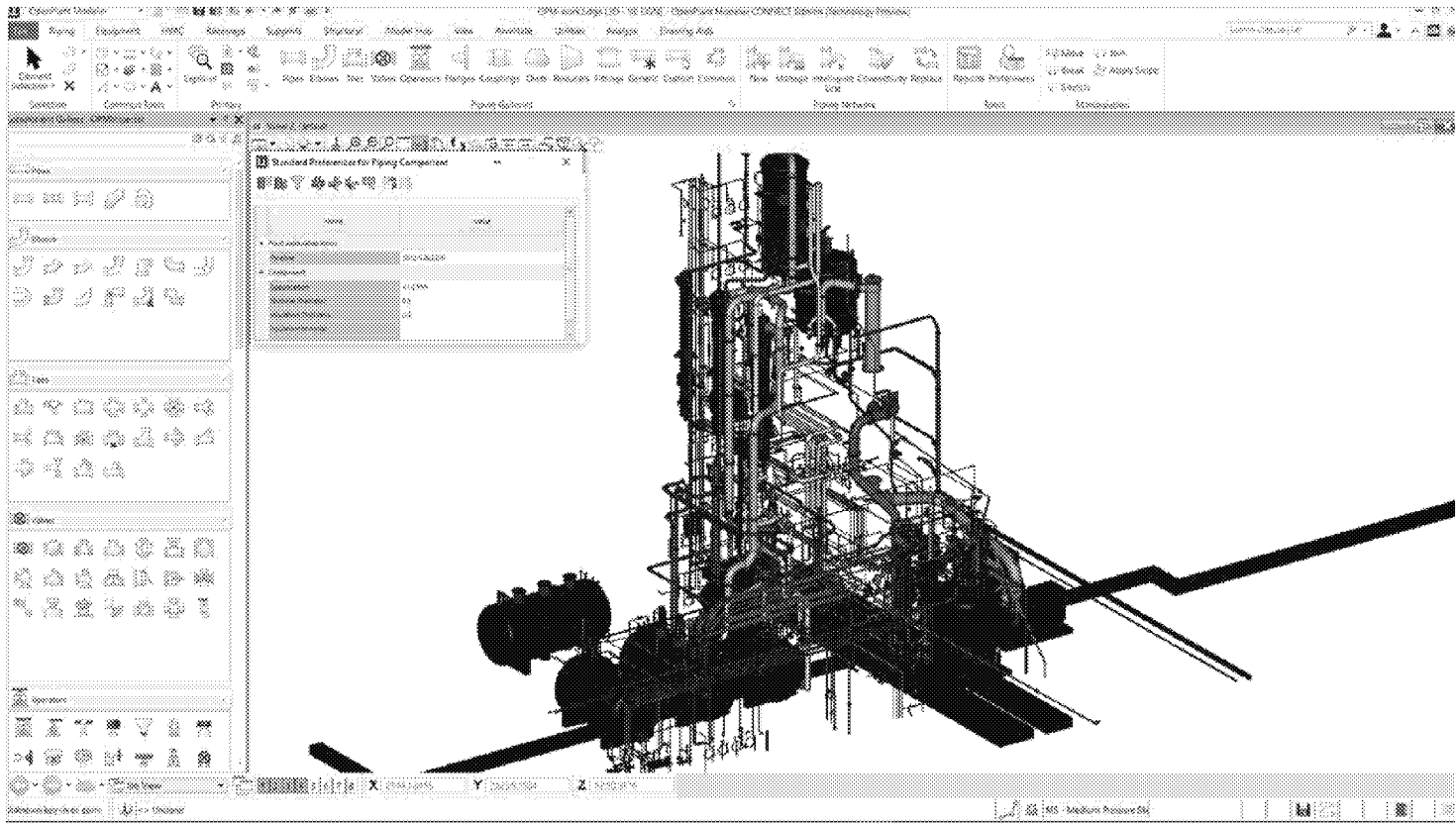
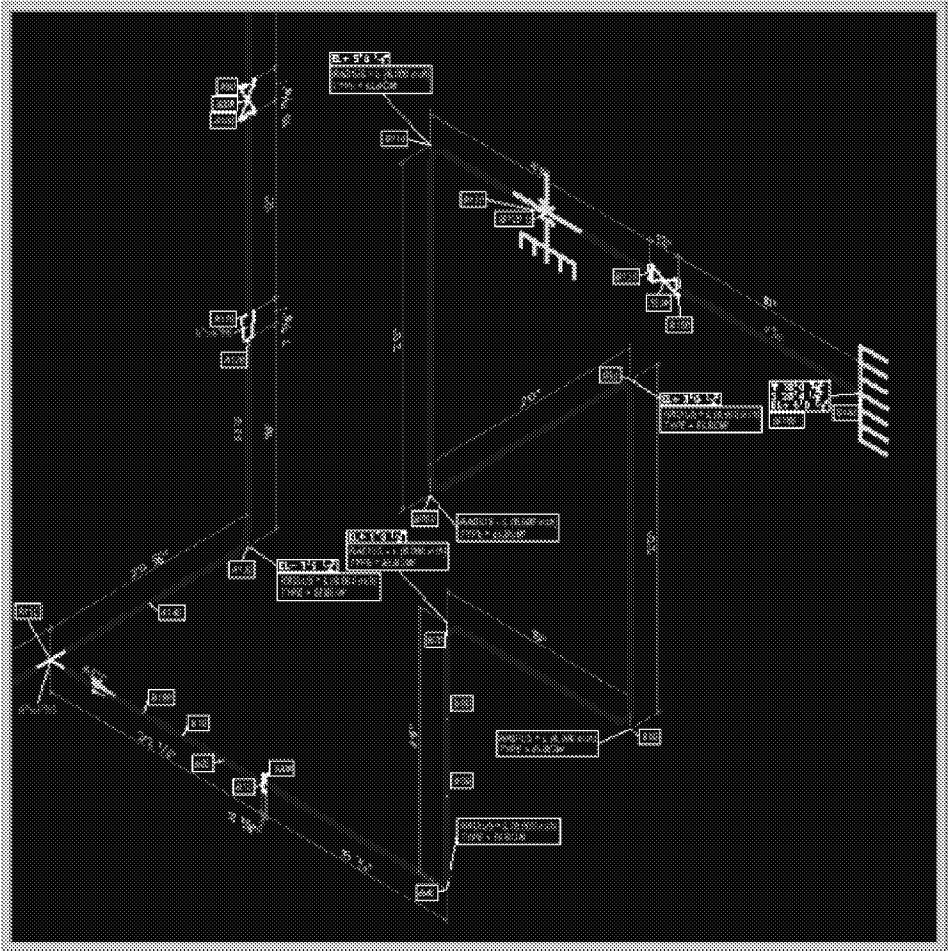
# Vertical Display



# OpenBuilding



# OpenPlant



# Summary

- Water distribution models can work in buildings
- Elevation data
- Pulse demands
- Results display





22 April 2020

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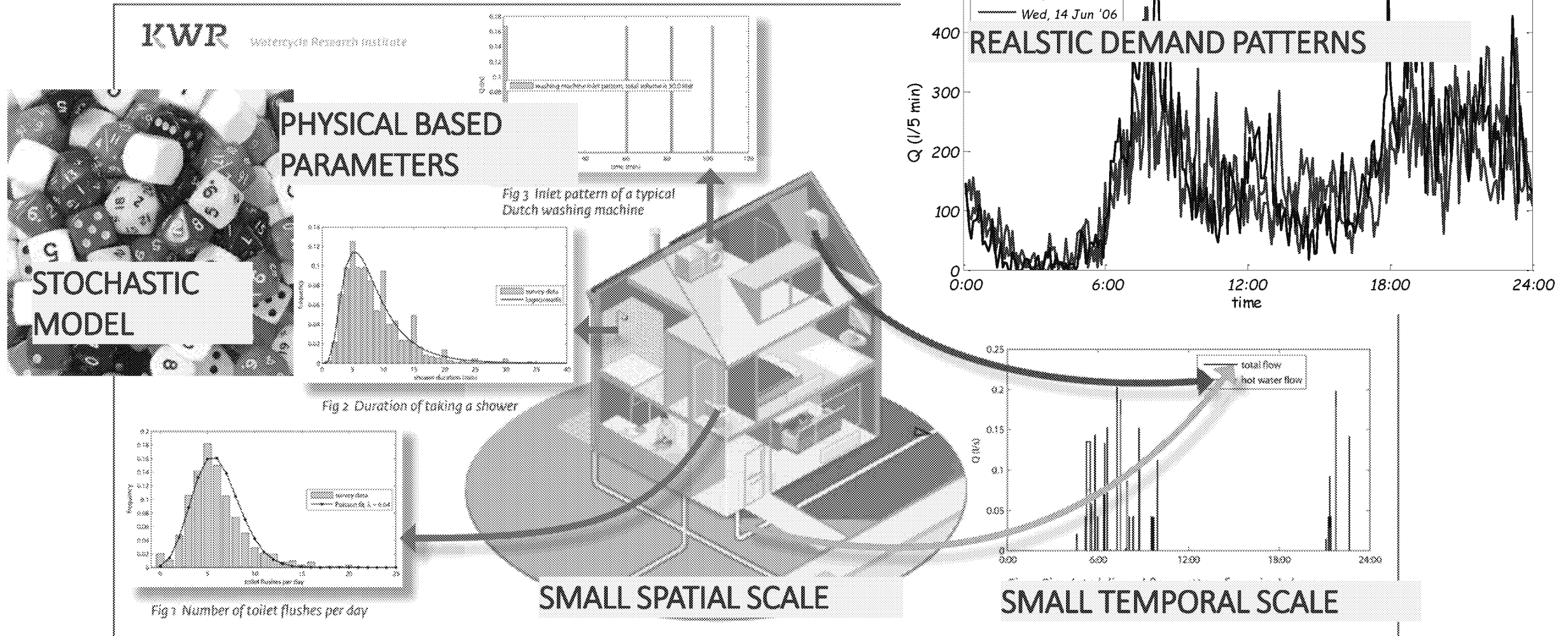
# Demand modelling

Premise plumbing modelling workshop



Bridging Science to Practice

# Demand modelling - SIMDEUM



## ~ SIMDEUM validations

Level of water meter (cold and hot), and aggregation up to 2000 homes:

- Average demand pattern
- Maximum flow rate
- Distribution of flow rate and change in flow rates
- Number of hours of water use per day
- Number of pulses of water use

All at various time steps:

- Hour, 15 min, 5 min, 1 min, 10 sec

Drinking water distribution network:

- Water age / residence times
- Pulse shape (NaCl dosing)
- Temperature (DDWI and DWDS)

Sewer:

- Flow rates and transport
- Nutrient load (P, N, COD, TSS) and temperature



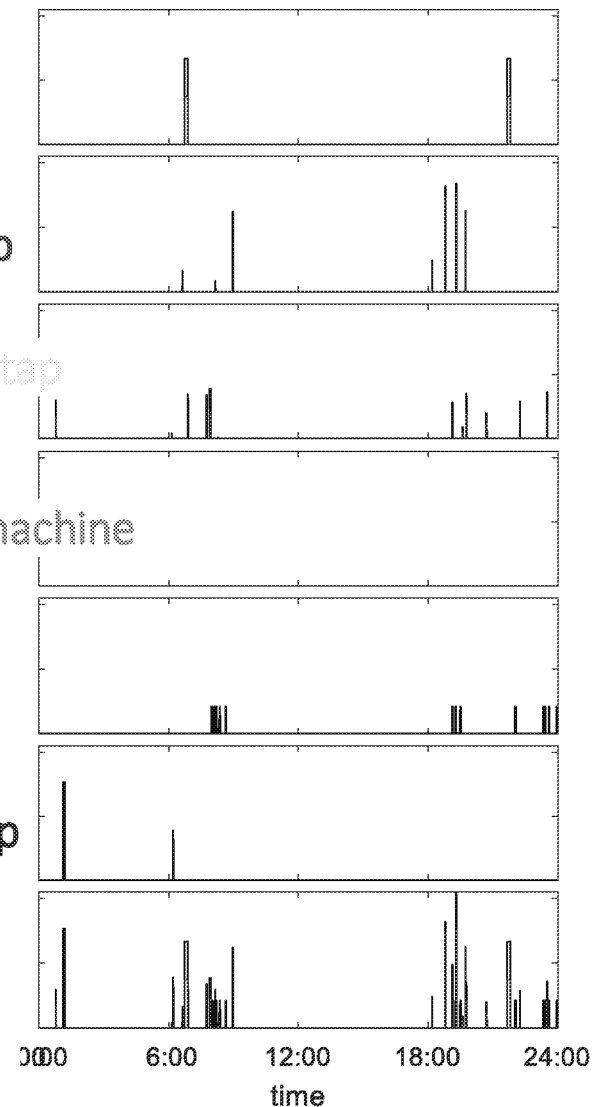
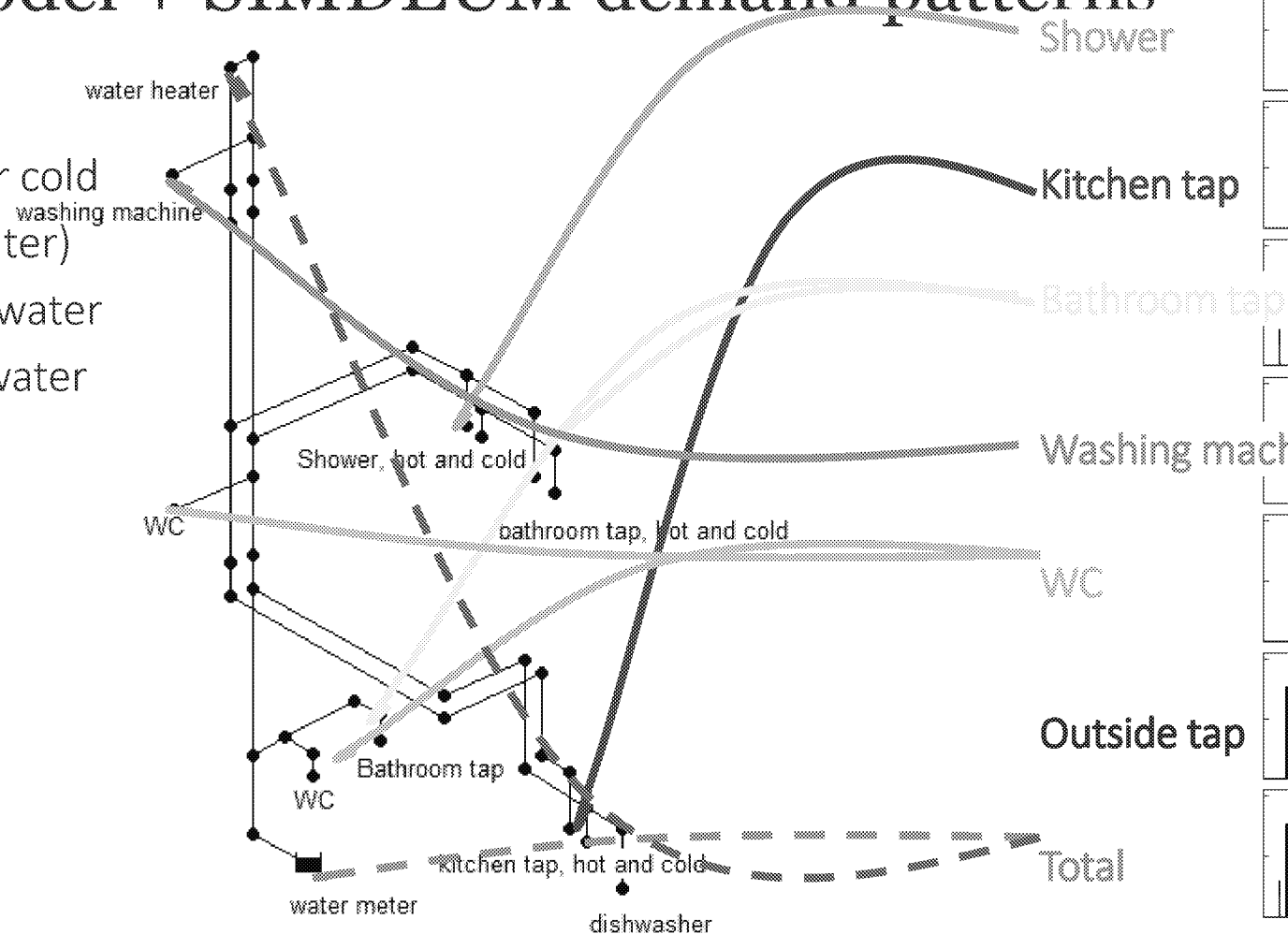
# Possible to model drinking water side: EPANET model + SIMDEUM demand patterns

## INPUT:

Demand patterns (for cold water, and for hot water)  
Temperature of cold water  
Temperature of hot water

## OUTPUT:

Hydraulics  
Water age  
(Water Quality)



# Also possible to model in home sewer? DRAINET + SIMDEUM-WW

## INPUT:

Discharge patterns

Temperature of waste water

Nutrient load (P, N, COD, TSS)

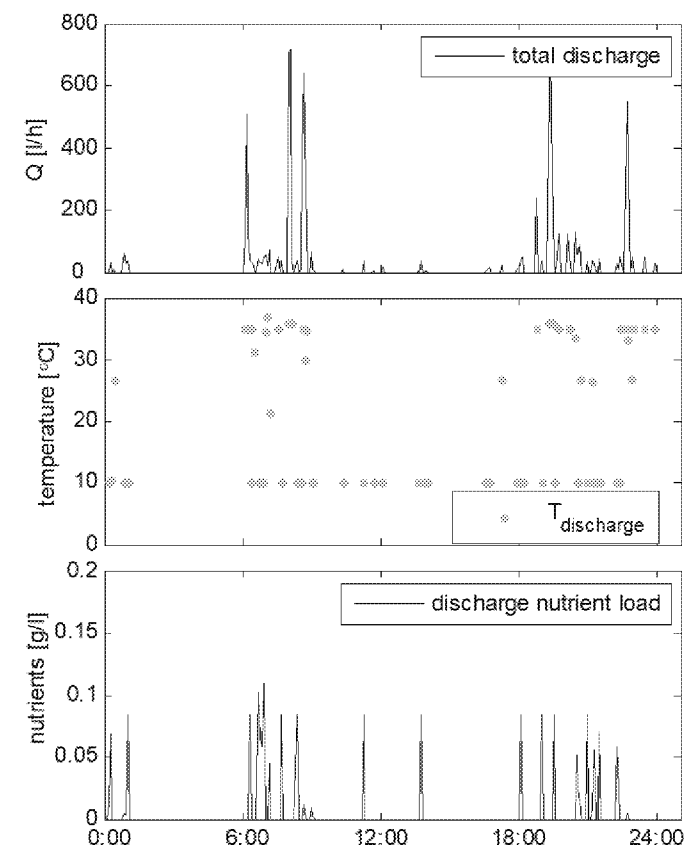
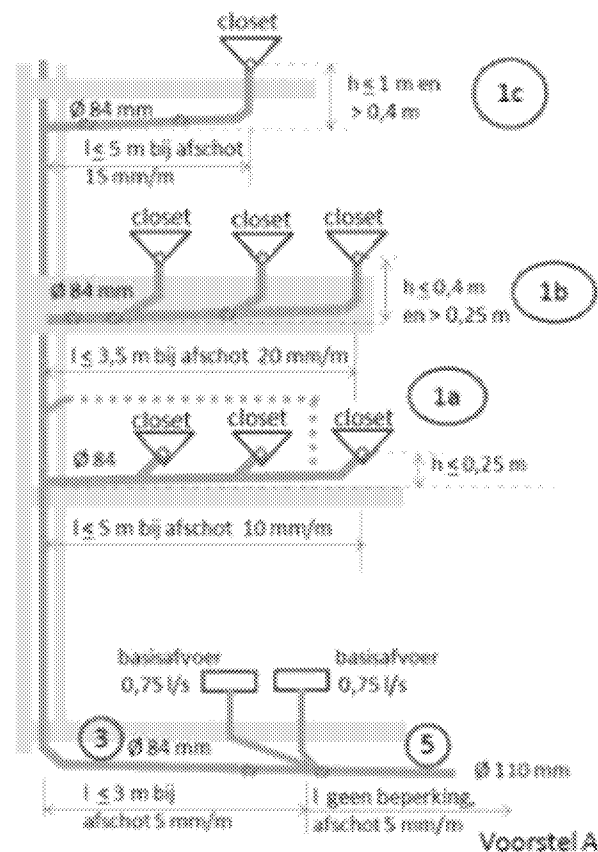
Viruses in faeces?

## OUTPUT:

Hydraulics

Nutrient transport

(Water Quality)



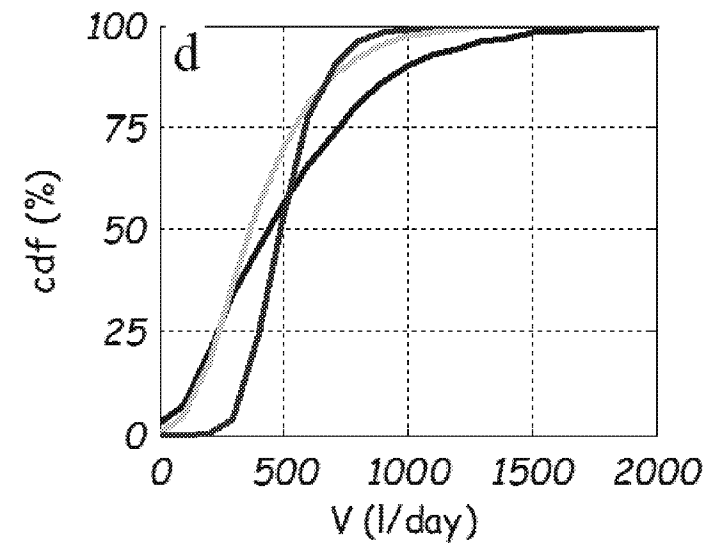
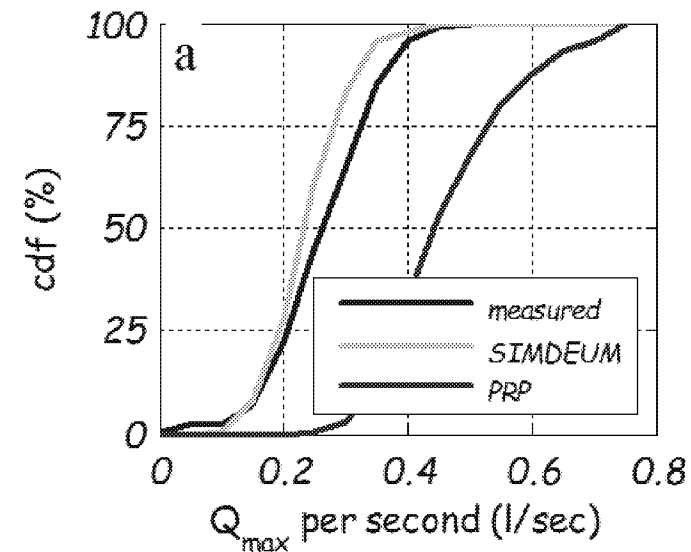
## Applications: water meter sizing

Water meter accuracy is related to its measurement range. So, insight into maximum flow rates helps to choose the proper water meter.

Qn 1.5: 0.4 L/s (nominal) – 0.8 L/s (max)

Qn 2.5: 0.7 L/s (nominal) – 1.4 L/s (max)

Average is 500L/day = 0.006 L/s

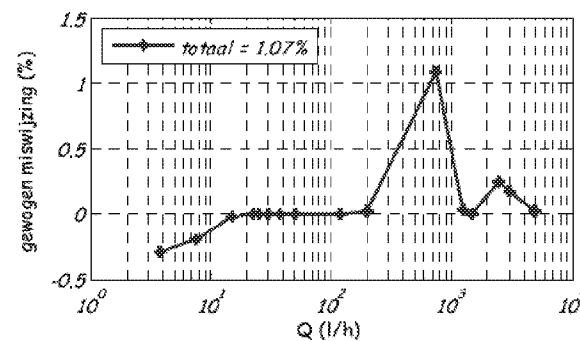
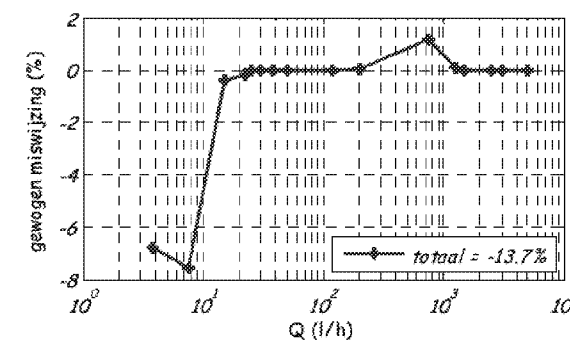
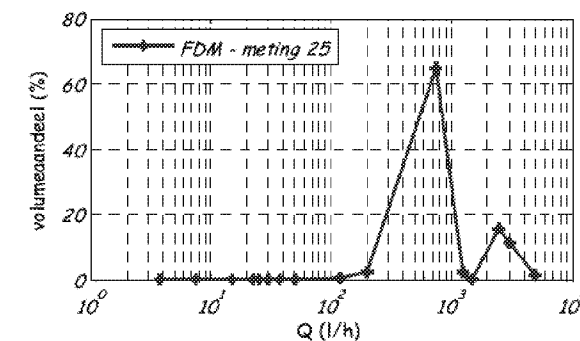
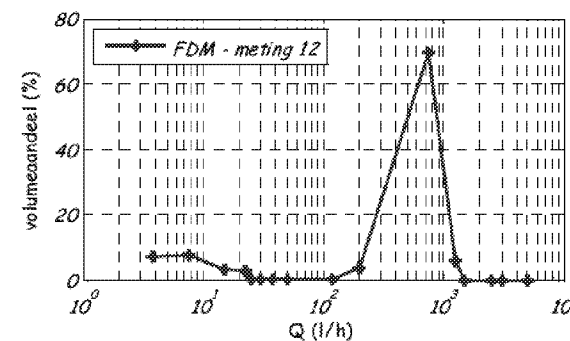
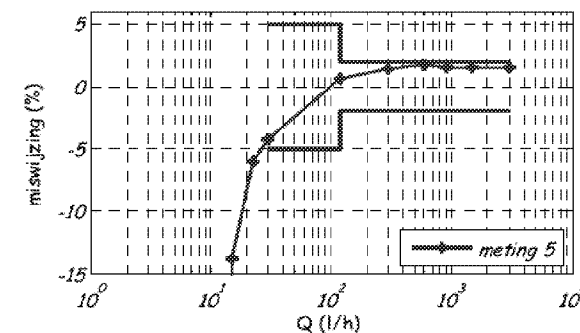
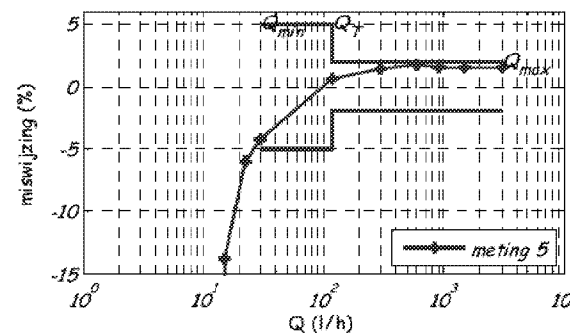


Blokker, E. J. M., Buchberger, S. G., Vreeburg, J. H. G. en van Dijk, J. C. (2008). "Comparison of water demand models: PRP and SIMDEUM applied to **Milford, Ohio**, data." WDSA 2008, J. E. van Zyl, A. A. Illemobade, en H. E. Jacobs, eds., Kruger National Park, South Africa, 182 - 195.

# Applications: water meter billing accuracy assessment

Water meter accuracy is tested at a few flow rates. Depending on demand per flow rate, the billing accuracy can be assessed.

In the example: -13.7% or +1,07% deviation



# Applications: research for water quality in DDWI

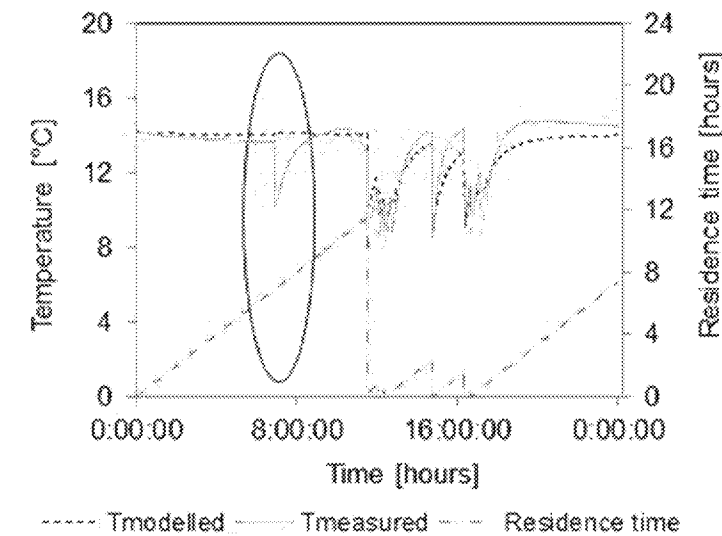
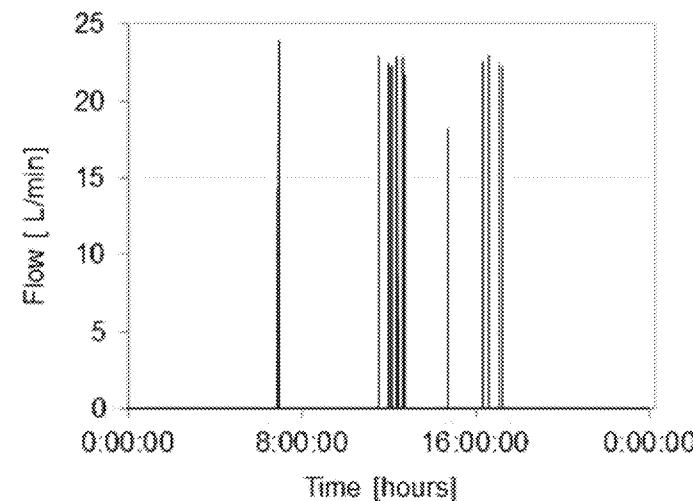
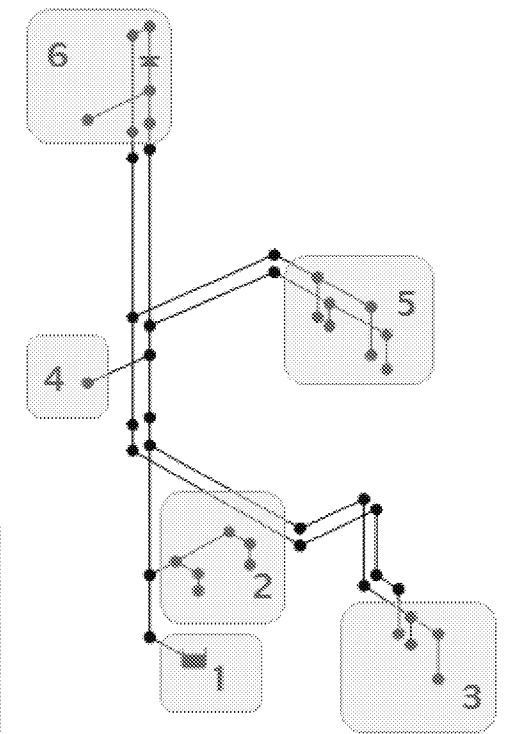
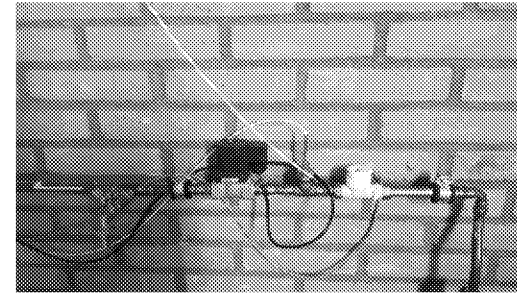
SIMDEUM used to put 365 unique demand patterns at all taps.

Temperature model was made and validated  
Effect of pipe length (network design) on water quality (water age, temperature, microbiological parameters) was studied

Picture: flow and temperature at kitchen tap

Zlatanović, L., Moerman, A., van der Hoek, J. P., Vreeburg, J. en Blokker, M. (2017). "Development and validation of a drinking water temperature model in domestic drinking water supply systems." *Urban Water Journal*, 1-7, doi:10.1080/1573062X.2017.1325501.

#	Group	Tap points
1	Water meter	N.A.
2	Ground floor toilet	Toilet, wash basin
3	Kitchen	Kitchen tap (C,H) Dishwasher
4	1 <sup>st</sup> floor toilet	Toilet
5	Bathroom	Shower (C,H) Wash stand (C,H)
6	3 <sup>rd</sup> floor	Washing machine Central heater (at check valve)



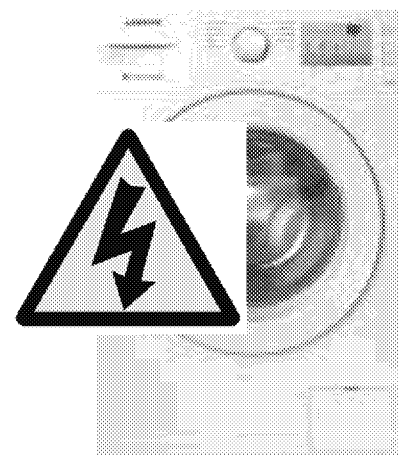
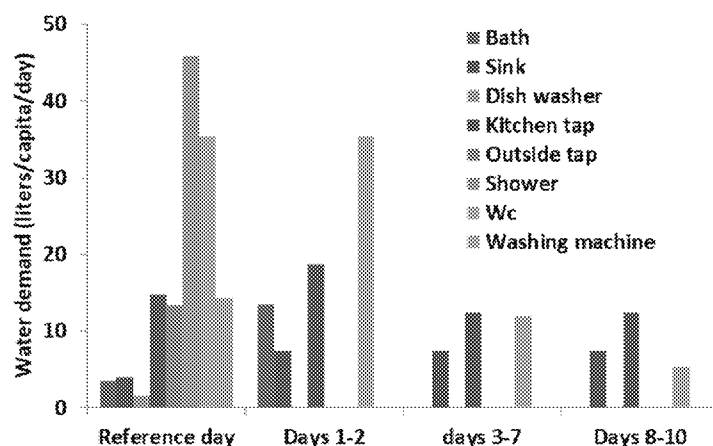
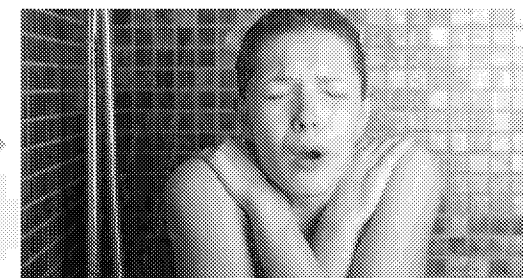
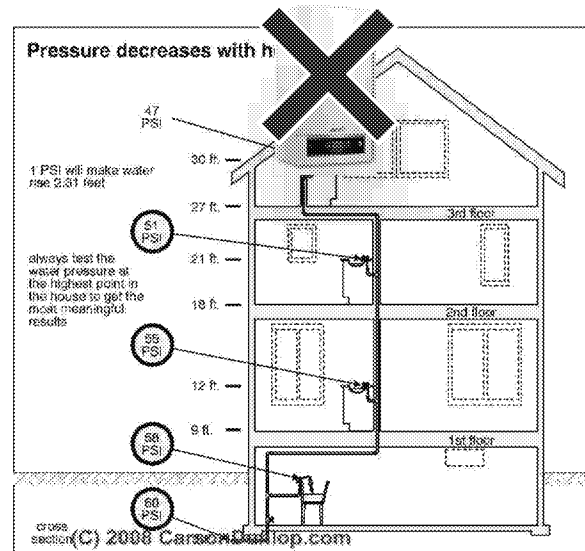
# Applications: demand under stressed conditions

With the help of SIMDEUM we determined

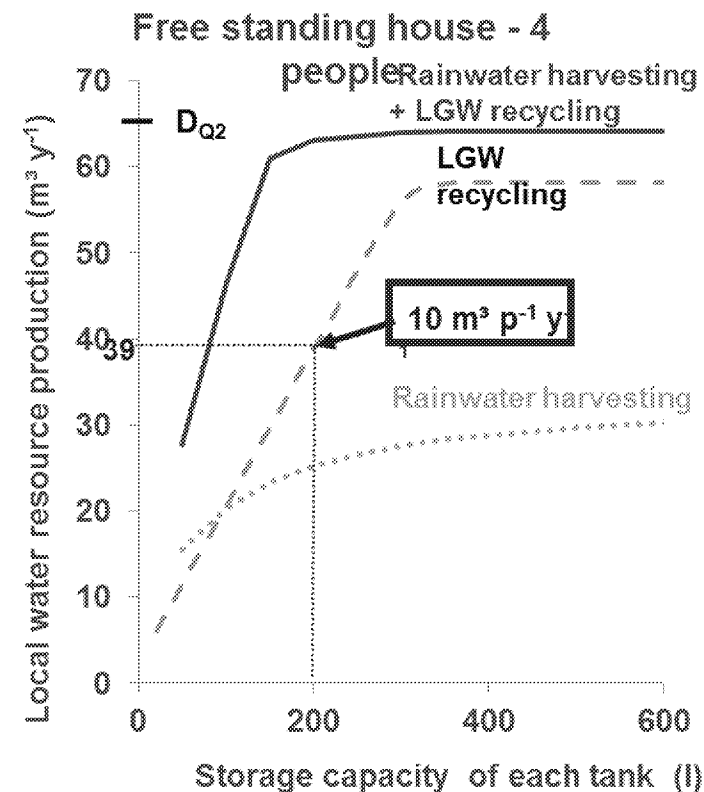
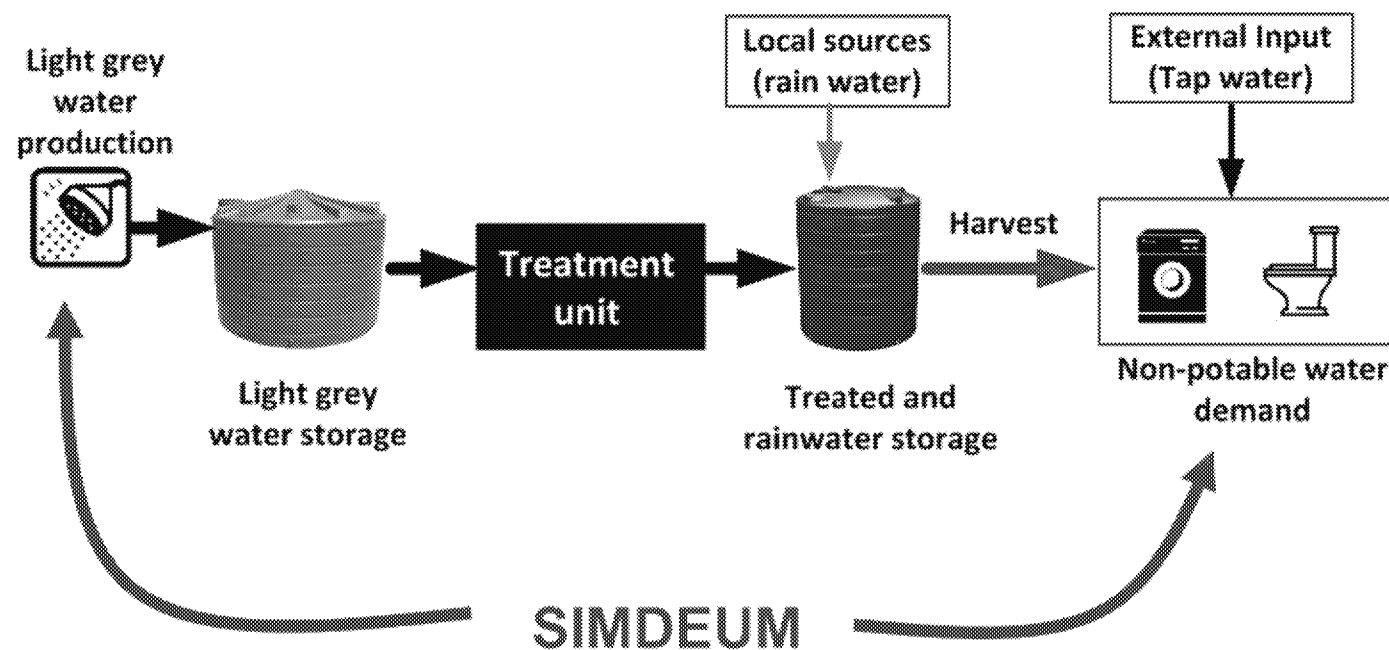
- 1) 'pressure adjusted demand'
- 2) 'electricity dependent demand'

And determined changes from regular demand

Blokker, E. J. M., Agudelo-Vera, C. M., Mesman, G. A. M., de Jong, S. en Adamse, E. (2018). "Drinking Water Demand under Stressed Conditions, Quantification with SIMDEUM." *1st International WDSA CCWI 2018 Joint Conference*, Kingston, Ontario, Canada.



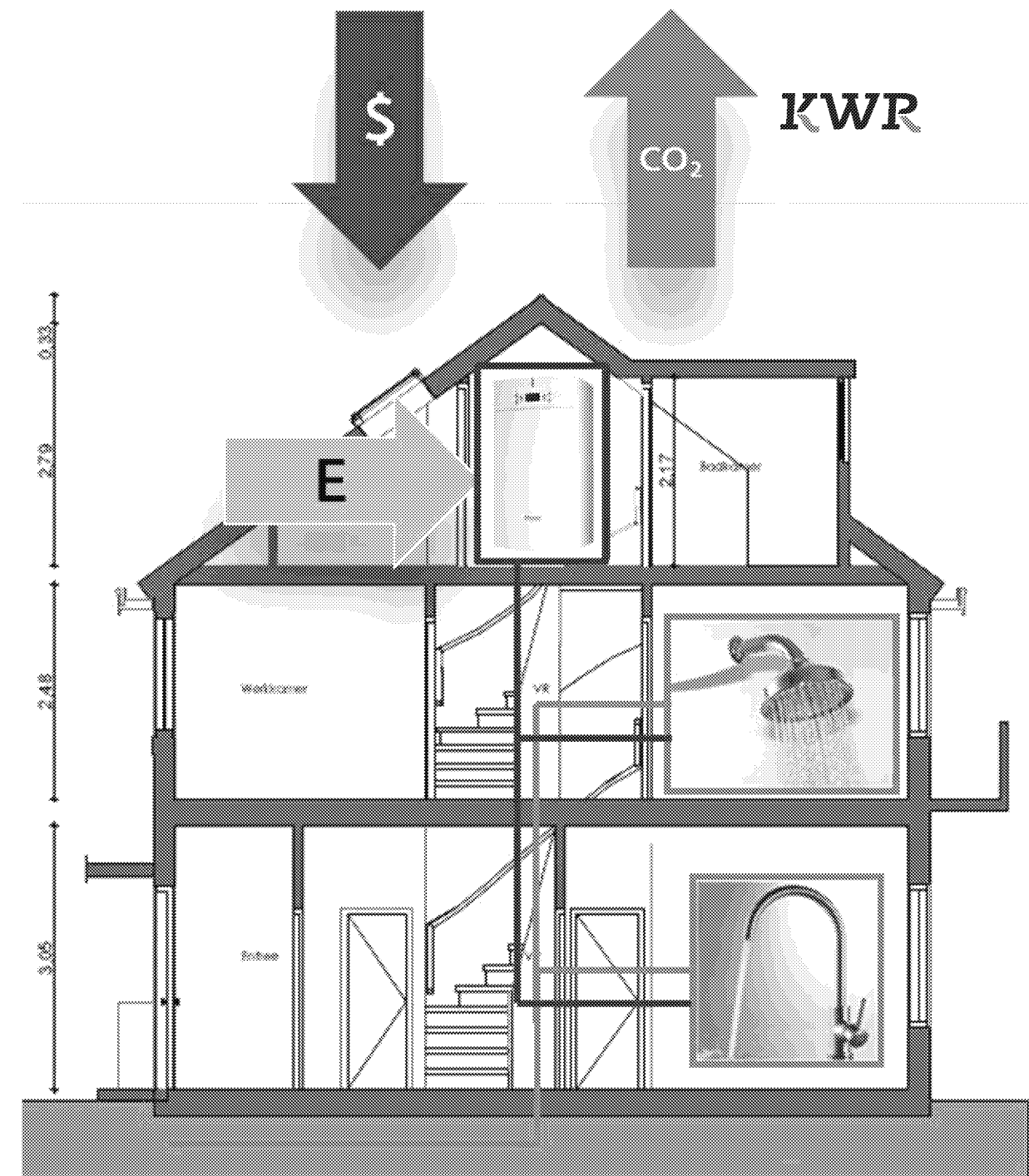
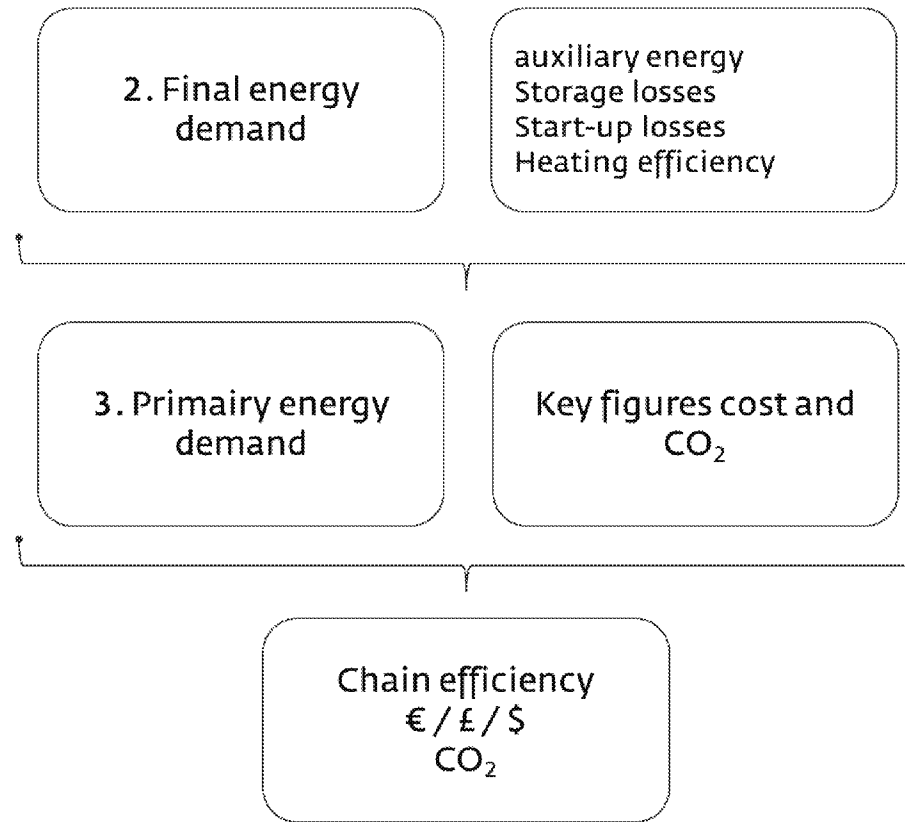
# Applications: grey water reuse



Is there enough grey water production for grey water use?  
What size of tank is needed?

Agudelo-Vera, C. M., Keesman, K. J., Mels, A. R. en Rijnaarts, H. H. M. (2013). "Evaluating the potential of improving residential water balance at building scale." *Water Research*, 47(December), 7287-7299.

# Applications: energy use for hot water

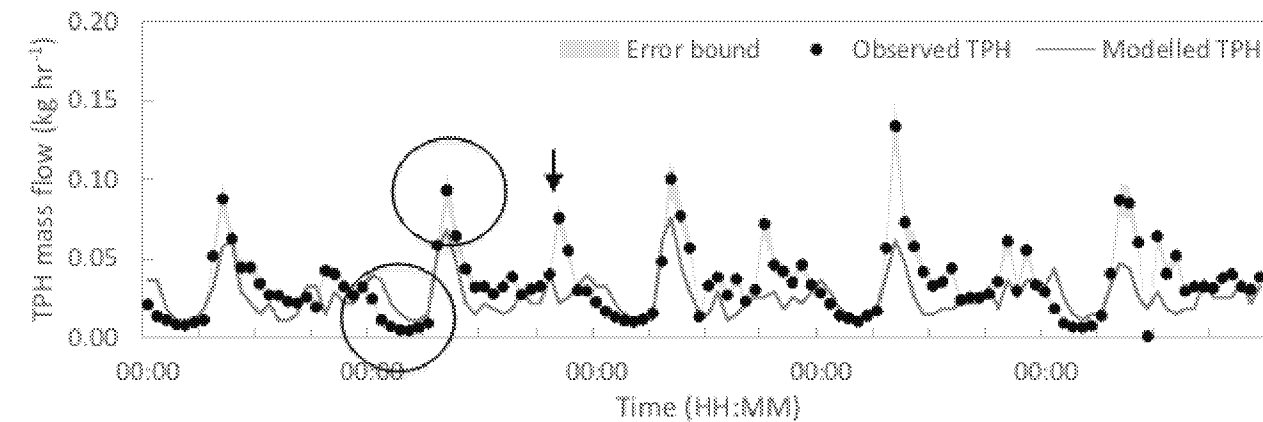
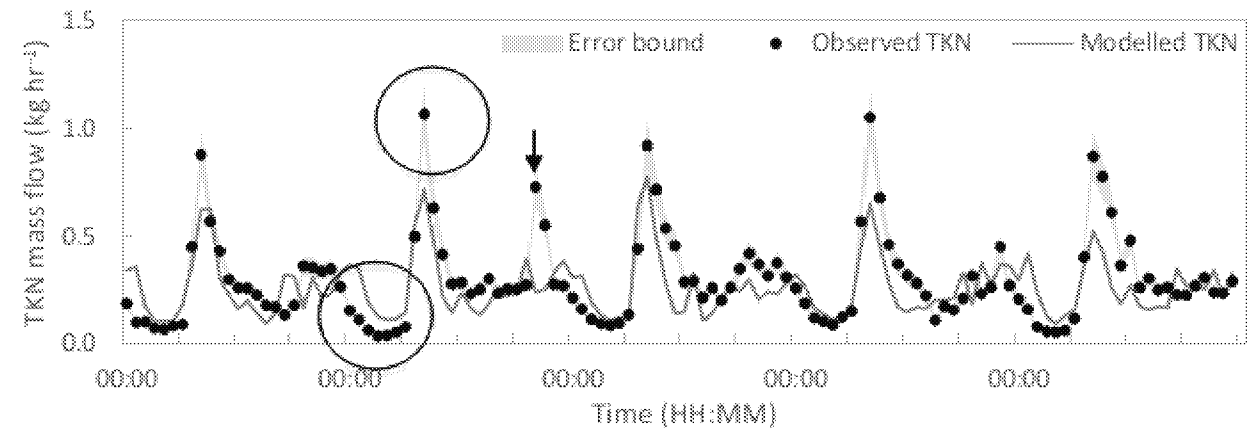


# Applications: sewer flows, temperature and nutrients

Model was validated in small sewer network (418 households and 55 small businesses)

Appliance	Temp. (°C)	Sewage Quality (g use <sup>-1</sup> )				Ref.
		COD	TKN	TPH	TSS	
Bath	36	25.90	0.85	0	8.88	1
Shower	35	12.60	0.49	0	4.32	1
Bathroom tap	40	1.48	0.04	0	0.56	1
Kitchen tap	40	7.48	0.35	0.03	4.68	1,2
Dishwasher	35	30.00	1.35	0	13.20	1
Washing machine	[35,35,35,45]	65.25	0.68	0	17.10	1
- With GWR		69.40	0.78	0	17.88	4
Toilet	23	11.22	1.99	0.22	3.04	2,3
- With GWR		11.48	2.00	0.22	3.09	4

<sup>1</sup> Parkinson et al. (1999, 2005), <sup>2</sup> Comber et al. (2013), <sup>3</sup> Blokker & Agudelo-Vera (2015) <sup>4</sup> Derived from Penn et al. (2012)



Hofman, J., Bailey, O., Zlatanovic, L., Van der Hoek, J. P., Kapelan, Z., Blokker, E. J. M. en Arnot, T. C. (submitted). "A stochastic model to predict flow, nutrient and temperature changes in a sewer under water conservation scenarios."

## Future work

pySIMDEUM, open source



Coupling with EPANET?

- To make full use of stochastic nature of demands
- To enable pressure adjusted demands

Potential to define some standard domestic drinking water installations

Use in drainage models, especially for apartment buildings.



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~  
**Mirjam Blokker**

E-mail: [mirjam.blokker@kwrwater.nl](mailto:mirjam.blokker@kwrwater.nl)  
06-15861099



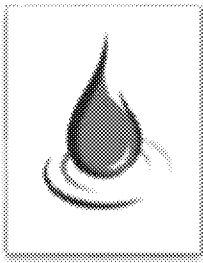


# Water quality issues in building water systems

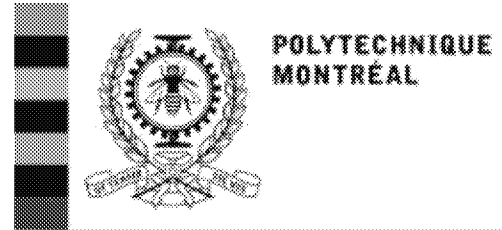
**Michèle Prévost**

*EPA PP modeling webinar*

*April 22nd 2020*



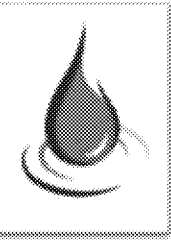
# Presentation outline



## 1. Overview of my research focus

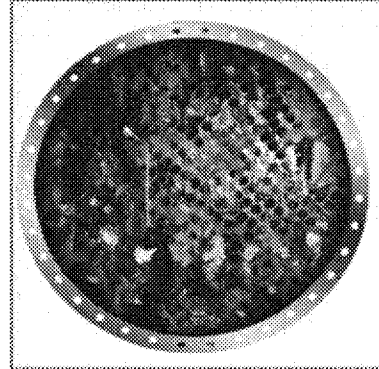
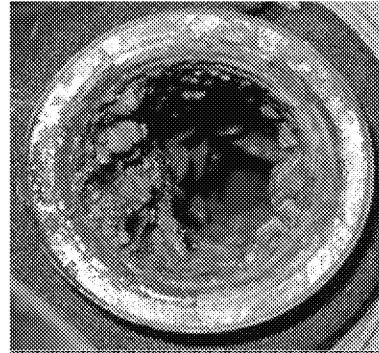
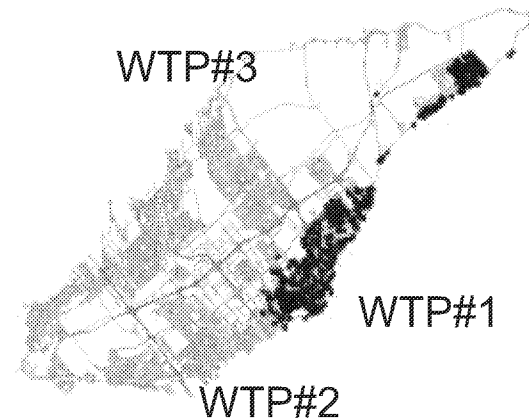
- Health outcomes
- Impact of water stagnation on lead release
- Impact of stagnation on microbial contamination
- Examples of hydraulic issues in large buildings and HCFs

## 2. Gaps in the application and development of modeling tools



# DS are a significant source of waterborne outbreaks

- **Significant portion of WBO caused by DS deficiencies** (Craun et al. 2001, 2006)
  - chemical and microbial contaminants entering the DS
  - acute breakdown and/or contamination of DS and reservoirs.
- **Health impacts of non-acute contamination events suggested by several studies**
- **Numerous studies on intermittent flow**
- **Backflow and syphonage**
- **Ingress**
  - ♦ Laval (2 studies) – Payment et al. (1991,1997)
  - ♦ UK, Hunter et al. (2005)



# Public Health Hospitalization Costs Associated with Contaminated U.S. Drinking Water

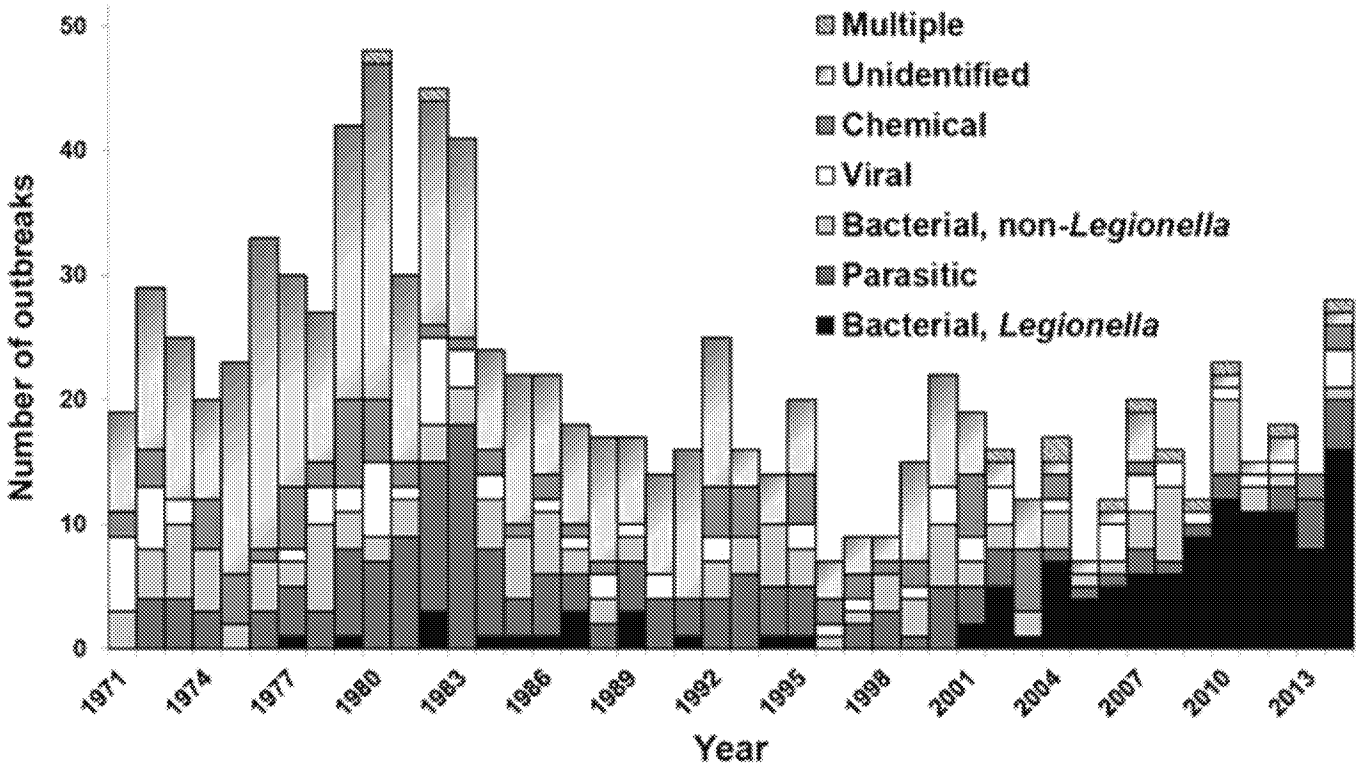
## CDC estimates drinking water disease costs > \$970 million/year

- Less so fecal pathogens
- Largely Legionnaires' disease, otitis externa, and non-tuberculous mycobacterial with >40,000 hospitalizations/year

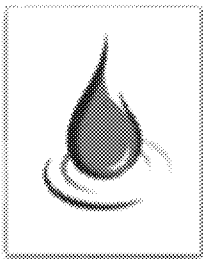
Disease	Annual costs
Cryptosporidiosis	\$46M
Giardiasis	\$34M
Legionnaires' disease	<b>\$434M</b>

Collier *et al.* (2012) Epi Inf 140(11): 2003-13

Figure 2. Etiology of drinking water associated outbreaks (n=928), by year, US, 1971-2014. Source: Benedict *et al.*, 2017



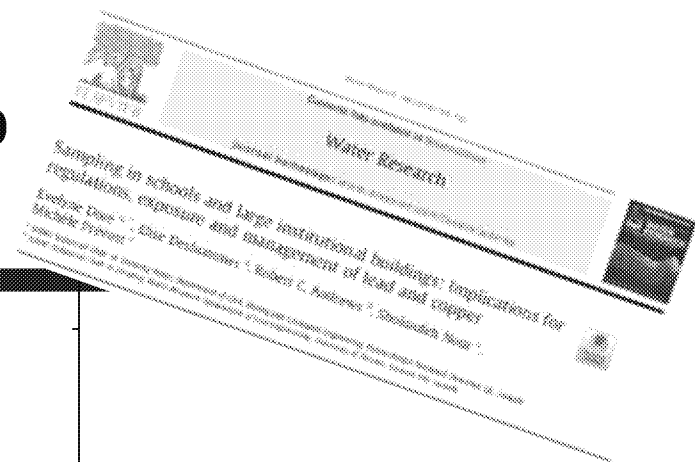
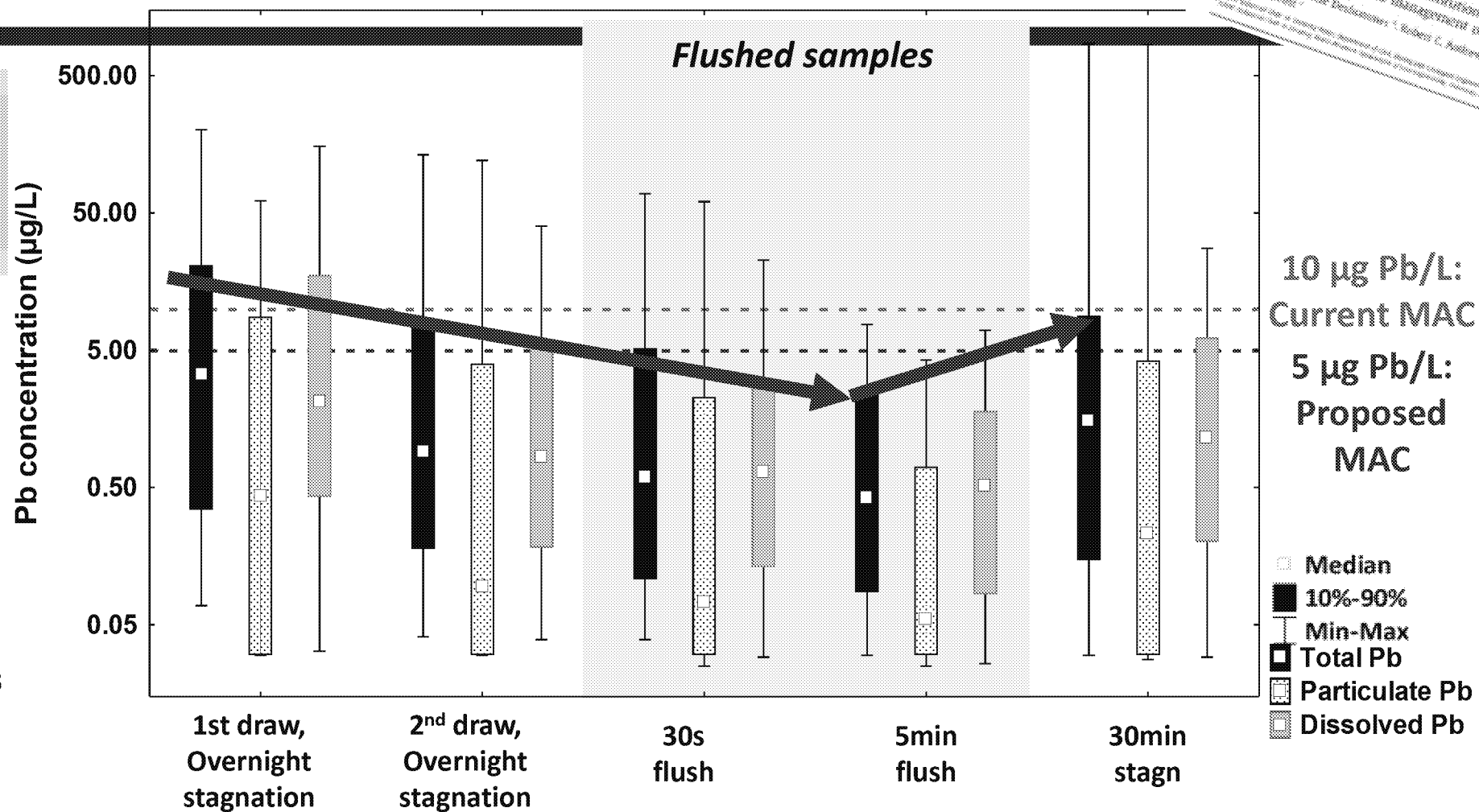
SOURCE: Benedict *et al.* (2017).

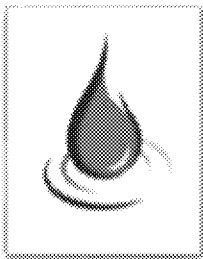


# Stagnation drives lead concentrations at the tap

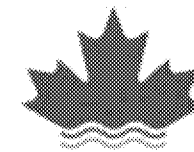


Results – Schools  
and large buildings  
Overall – 130 taps, 3  
water qualities

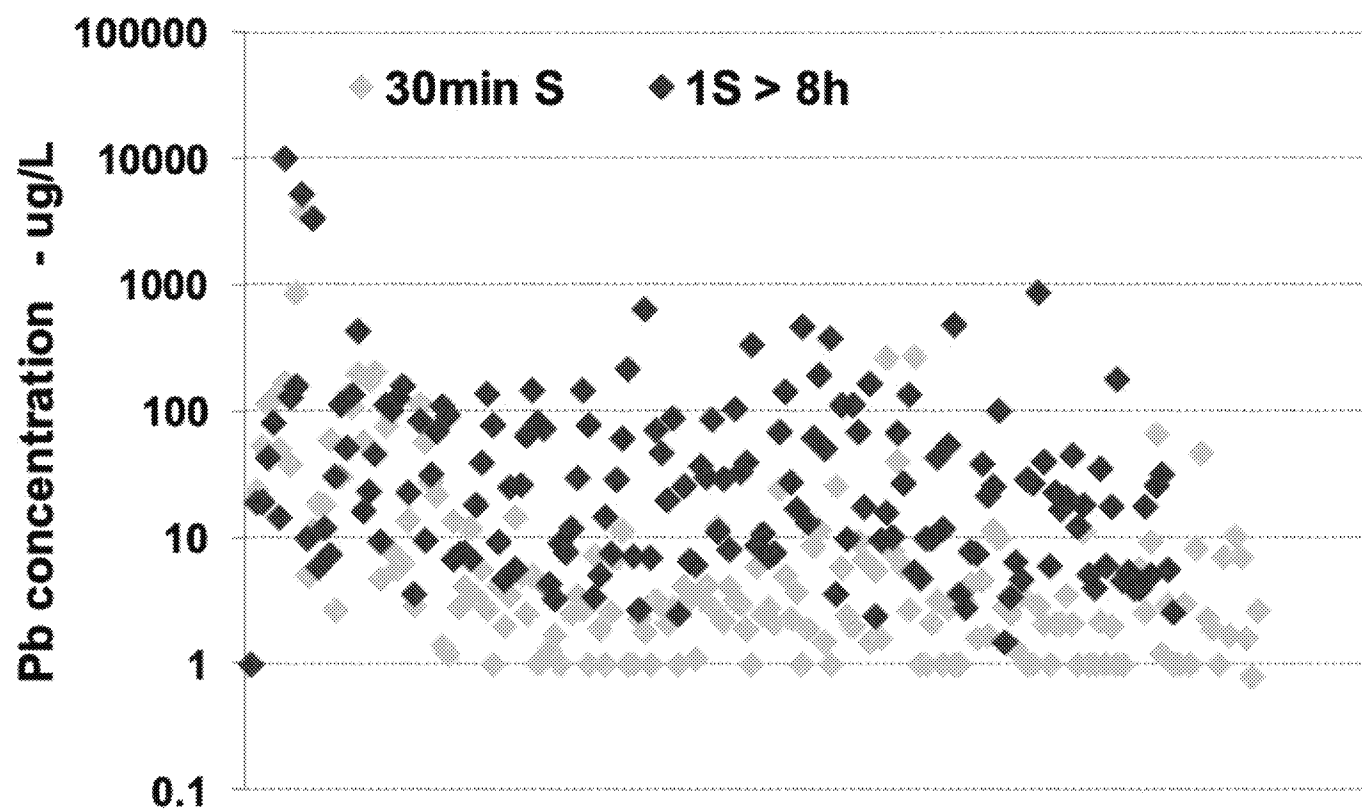




# Impact of stagnation on Pb in large buildings: Variability within a single building



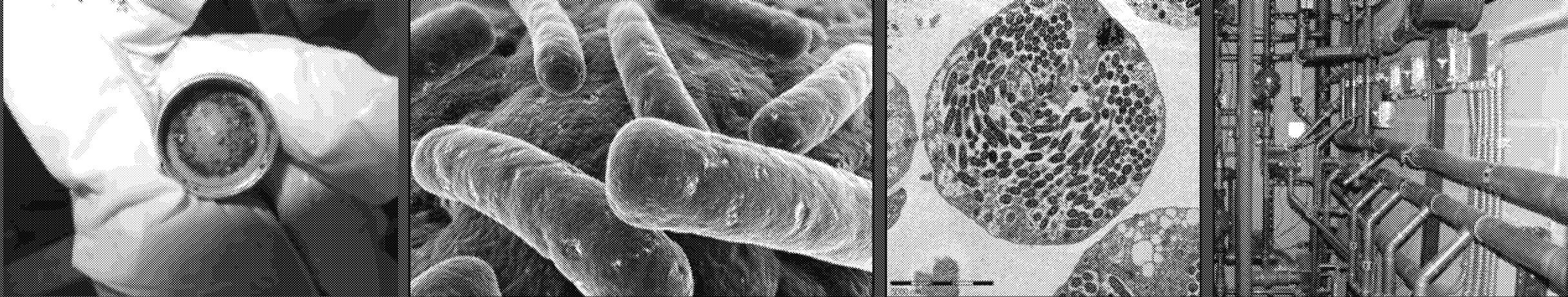
CANADIAN WATER NETWORK  
RÉSEAU CANADIEN DE L'EAU



*Deshommes et al 2016*

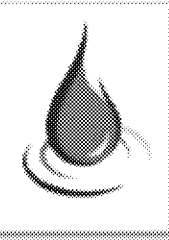


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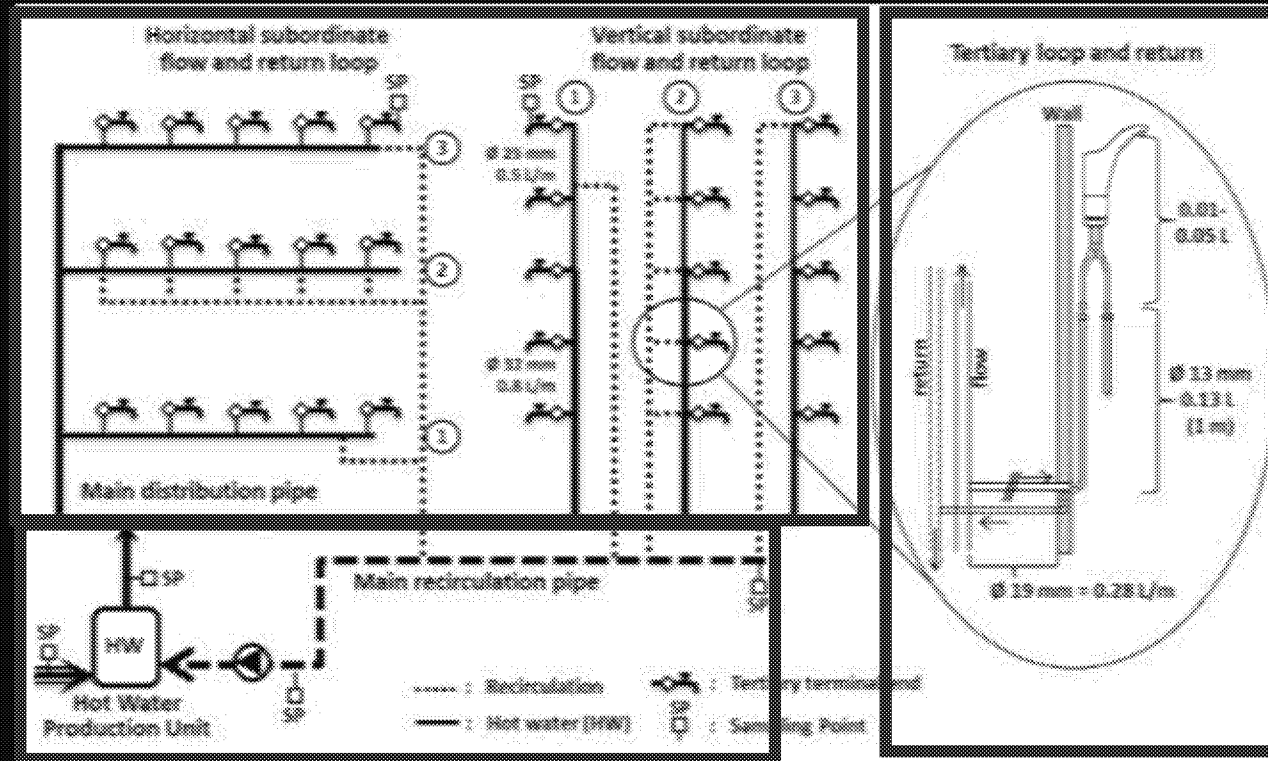
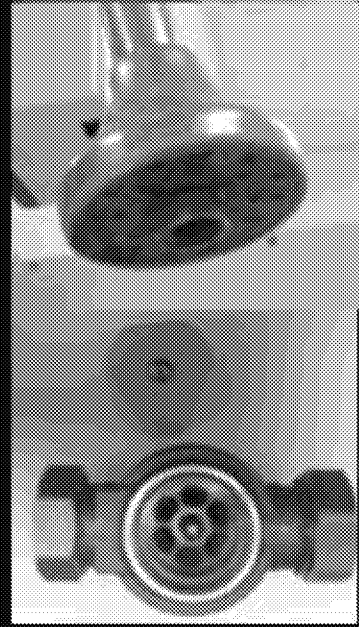
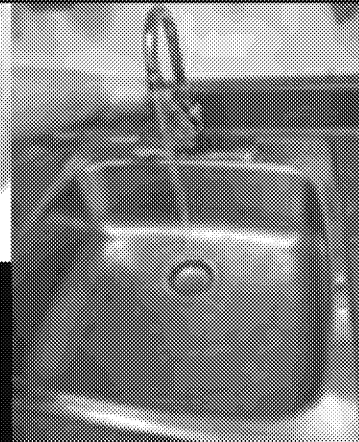
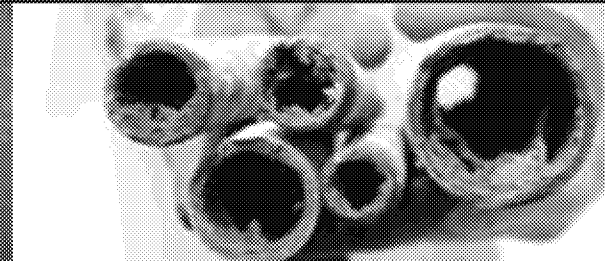
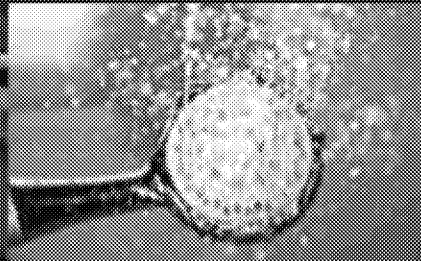
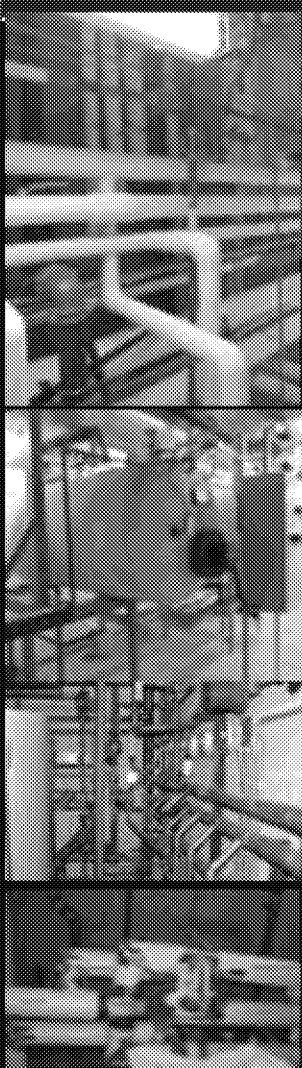
## Recent research on the control of pathogens in large buildings

- Identifying niches of pathogens in hot and cold water systems that drive infection risks
- Role of aerators as a vector of infection
- Impact of materials on the resistance of Lp to disinfection
- Defining optimized thermal control regimes
- Unintended consequences of water and energy conservation
- Redesign of the sink environment in HCFs to prevent neonatal infections
- Commissioning (and coVid recommissioning) of cold and hot water systems
- Impact of materials on pathogens and hosts
- Estimation of health risk using QMRA



# Building water systems are complex

Niches for pathogens in buildings



# Why is it important to master hydraulics in HWS?

## Strategies to control *Legionella* in water systems

### Evidence of temperature control in building water systems

- Large longitudinal studies in hospitals across several countries
- Extensive post regulation implementation monitoring in German hot water systems

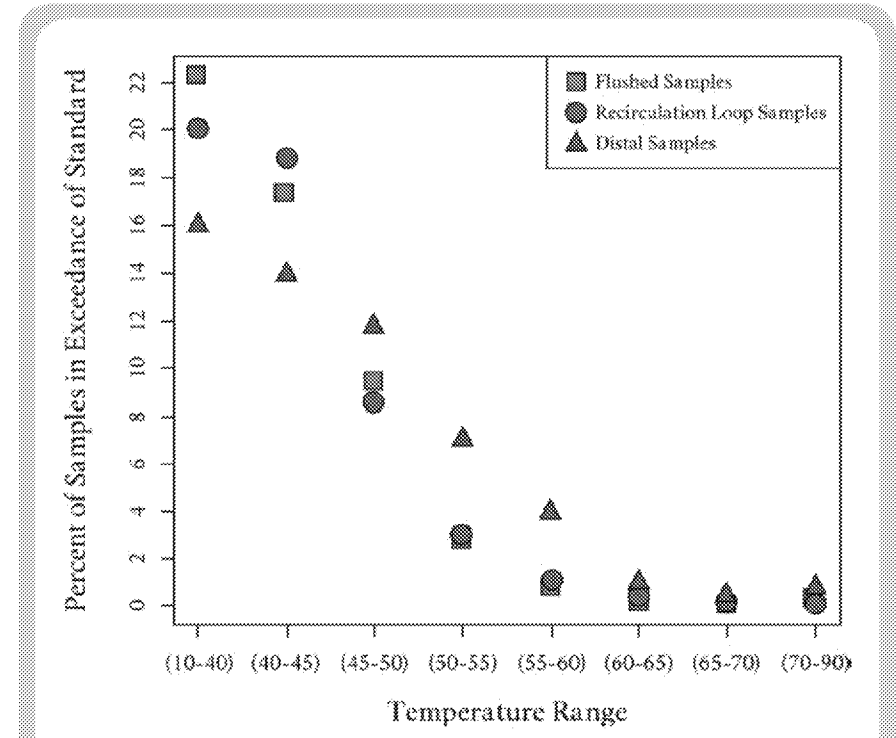
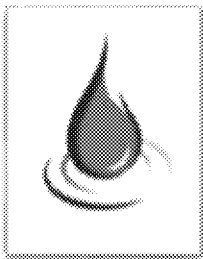
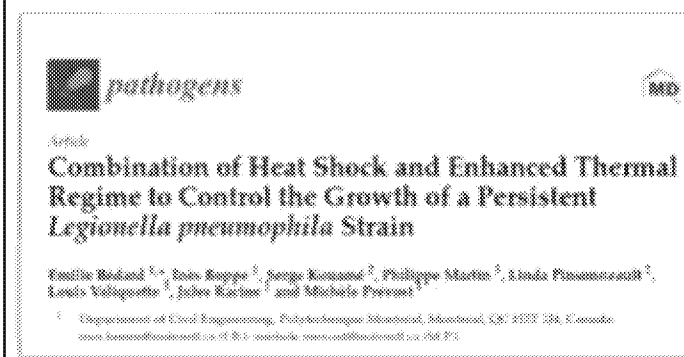
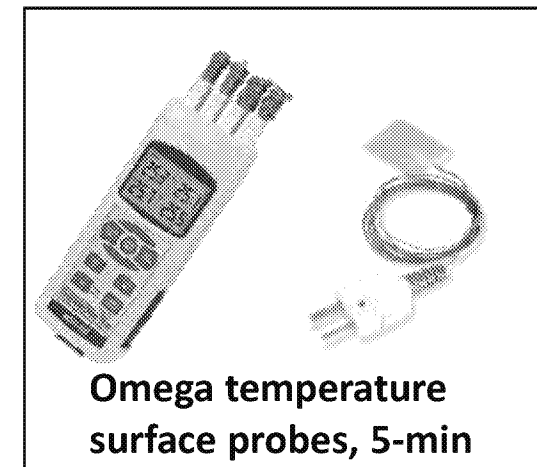
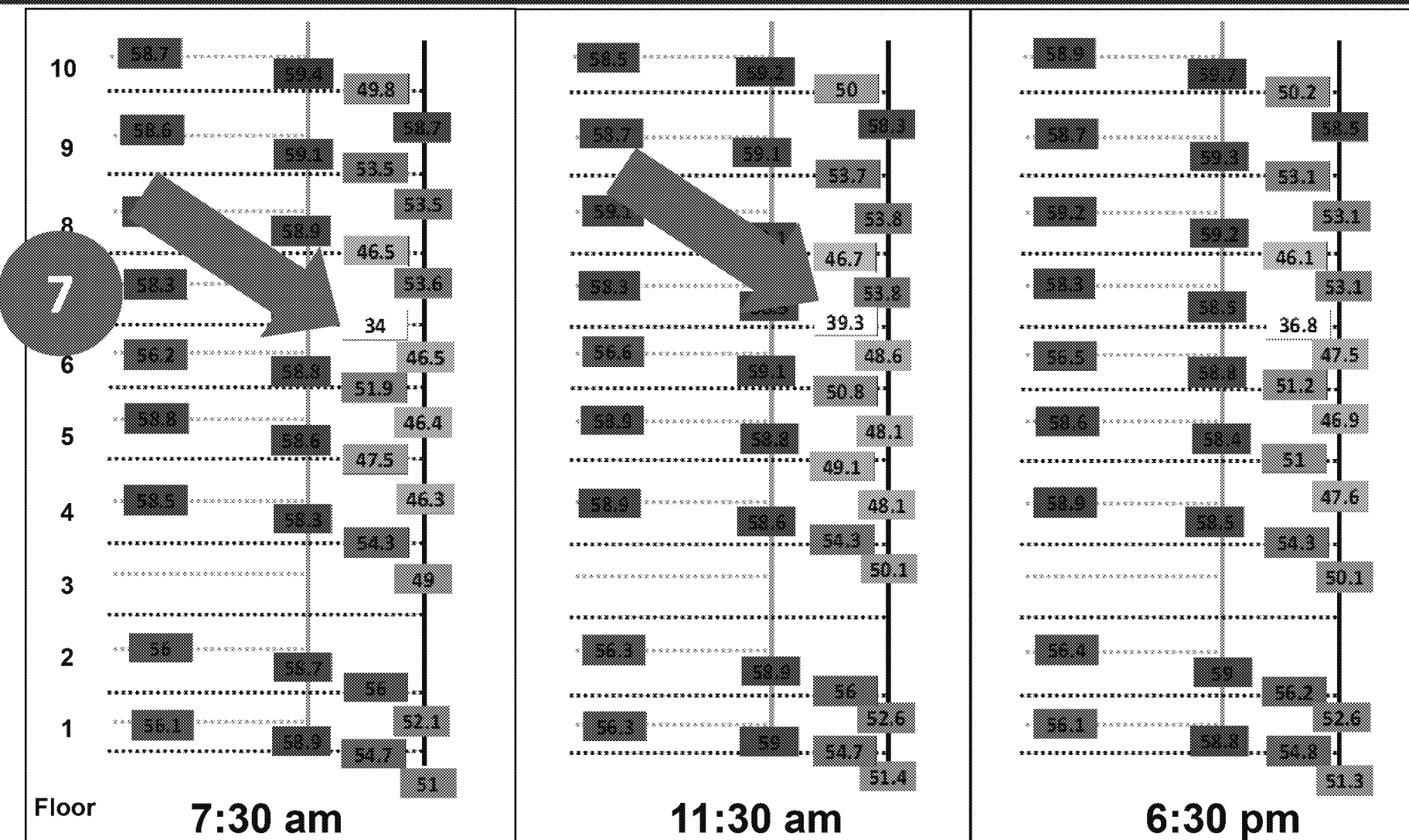


FIGURE 4. This chart shows the relationship between water temperature (x-axis) and the percent of samples exceeding the German standard of 100 CFU/100mL for *Legionella* spp. (y-axis) from public buildings in Germany over a seven-year period. Squares indicate flushed samples, circles indicate samples from the recirculation loop of the hot-water system, and triangles are samples taken from the distal ends of the plumbing. SOURCE: Kistemann and Wasser (2018).



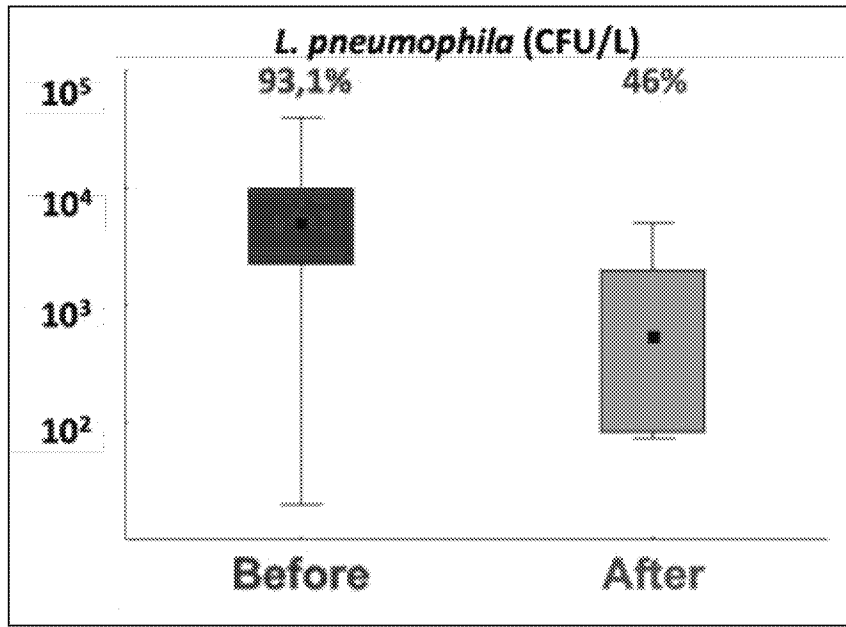
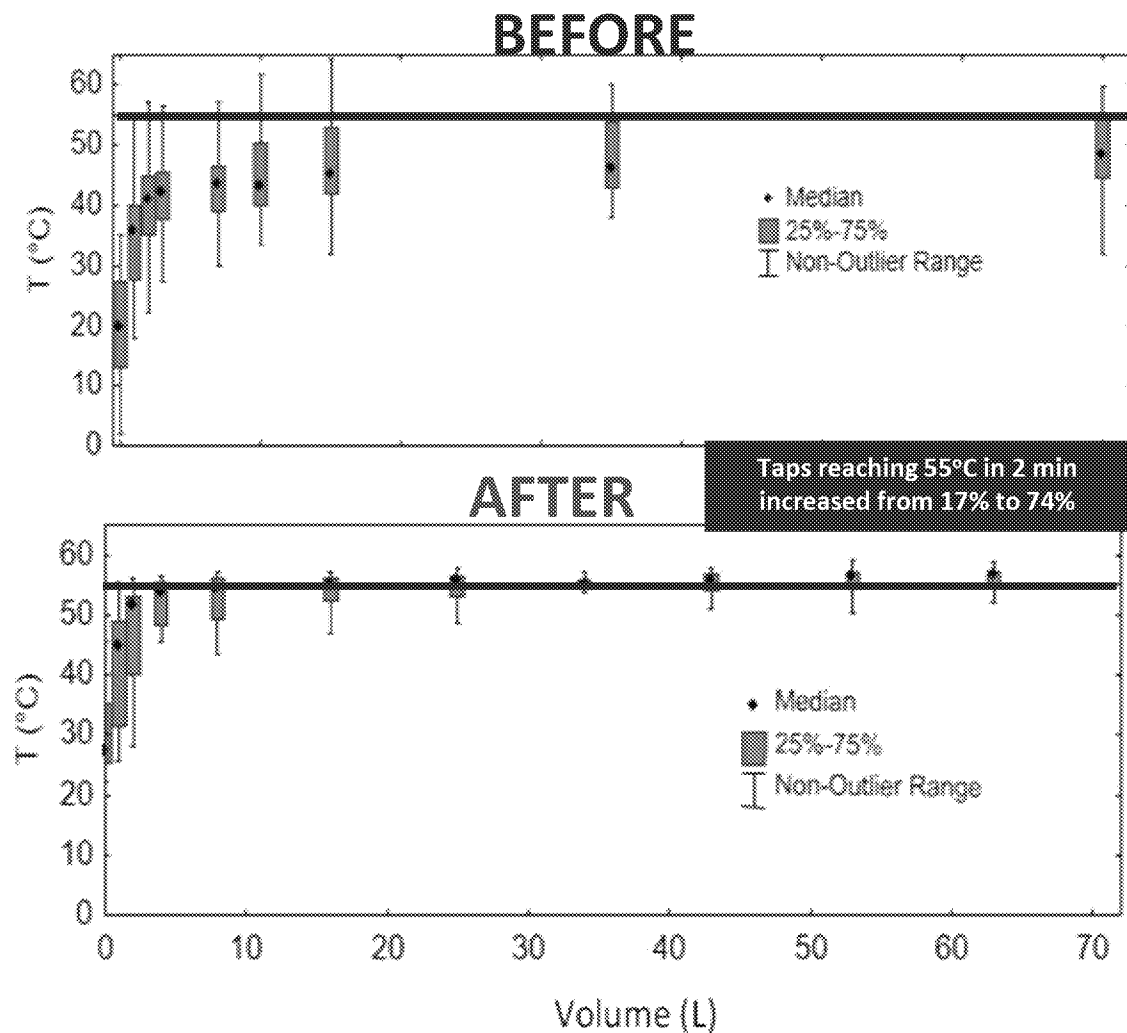
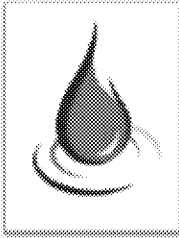
# Why fine balancing is needed?

## Temperature monitoring in secondary return loops

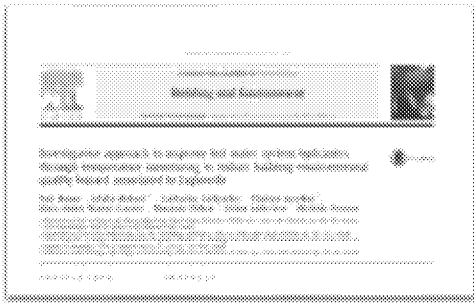


# Pediatric hospital temperature profiles

## Impact of hydraulic balancing



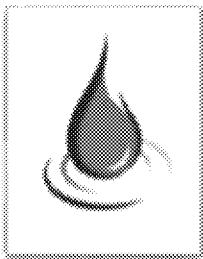
- Corrective measures**
- Balancing return loops
  - Fixing defective valves



# Strategies for *Legionella* in Various Water Systems

Control Strategy	Building Water Systems			Large Engineered Systems				Other Devices	
	Large Institutional Buildings	Green Buildings	Households	Potable Water Supply	Wastewater Treatment	Reclaimed Water Systems	Cooling Towers	Humidifiers	Hot Tubs
Temperature Control	✓	X	✓	?			?	✓	
Disinfection	✓	✓	?	✓	?	✓	✓		✓
Manage Hydraulics	✓	X	✓	✓		✓	✓	✓	
Nutrient Limitation				?		✓		✓	
Plumbing Materials	✓	✓	✓	?		✓	✓		
Distal Portion of Plumbing	✓	X	✓						
Aerosol Control	✓	✓	✓		✓		✓		

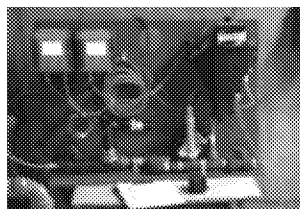
✓—Evidence of control working, ?—Potential for control working but some limitations, X—building type works against a control



# LEED School case study

## Residual chlorine

- **LEED design**
  - 4,7 L/min during daytime
  - 12 L/min peak flow
- **Boiling advisory**
- **Implementation of continuous flushing at tap (end point)**
- **>80 hours at 10 L/min**



### Cold Water System

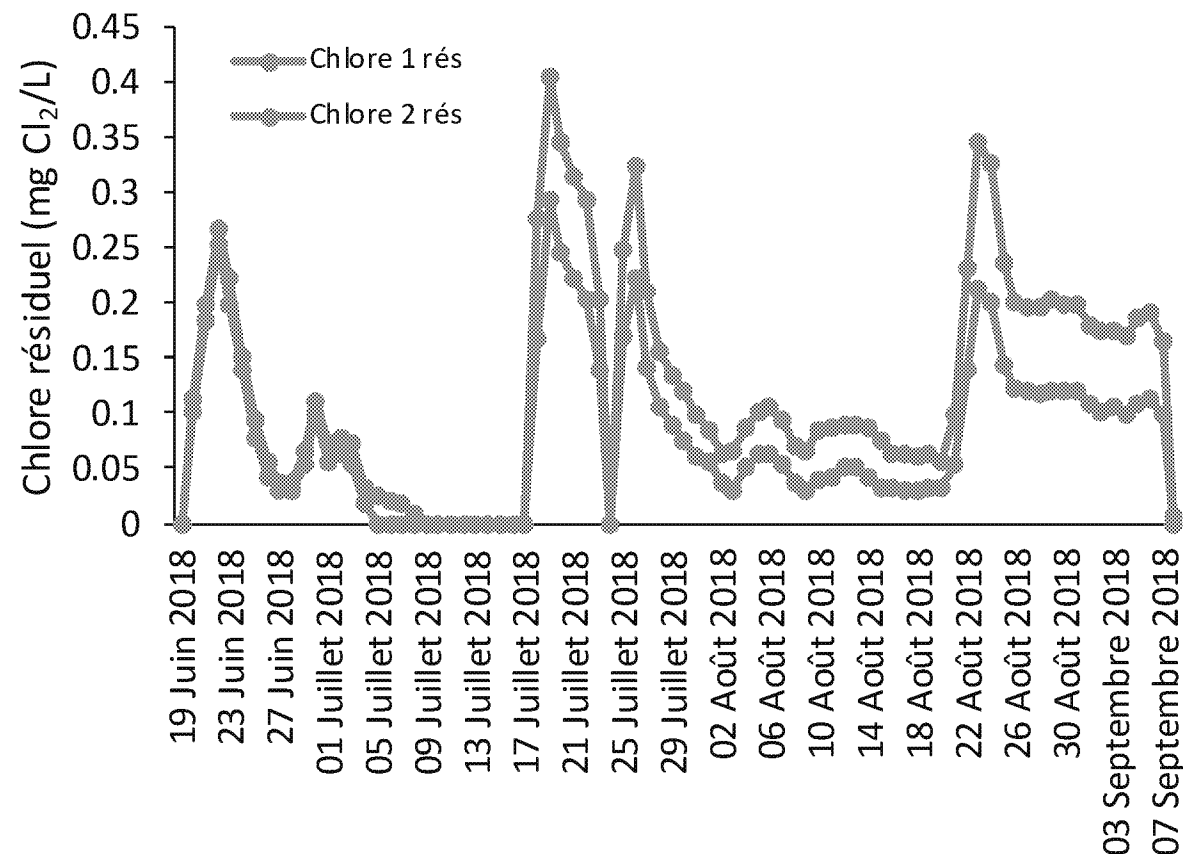
Diam = 76 mm

Length = 100 m

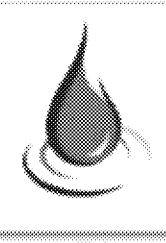
Volume = 460 L

+ HW & CW sec =

> 1,000 L



# Gaps in the development and application of modeling tools



- **Models of hot and cold water systems in large buildings to:**
  - Adjust operations to minimize the release of metals and the growth of pathogens (*Legionella*, NTM, *P.a.*, etc.)
    - Target hot and cold water systems
    - Include materials and varying stagnation patterns
  - Determine if and how much residual can be maintained in large buildings
  - Assess the risk of water and energy conservation measures in existing buildings
  - Review the design of new buildings to avoid extended stagnation/WQ losses resulting from low water demand
  - Assist building operators in siting of automatic flushes
- **Develop smooth interfaces with QMRA models to make use of hydraulic model outputs**
  - Use QMRA to decide where to act in large buildings to reduce health risks

# **Increase Customer Satisfaction by Improving the Performance of Premise Plumbing Systems**

**Premise Plumbing Workshop  
Webinar April 22, 2020**

**Gary Klein**

[gary@garykleinassociates.com](mailto:gary@garykleinassociates.com)

**916-549-7080**

# Topics

- What Are We Aiming For?
- Where Did All the Pressure Go?
- Why Does it Take so Long for Hot Water to Arrive?
- How Do We Increase Customer Satisfaction?
- How Does all this Affect Water and Energy Modeling for Premise Plumbing Systems?

# Water Consumption 1980-2017

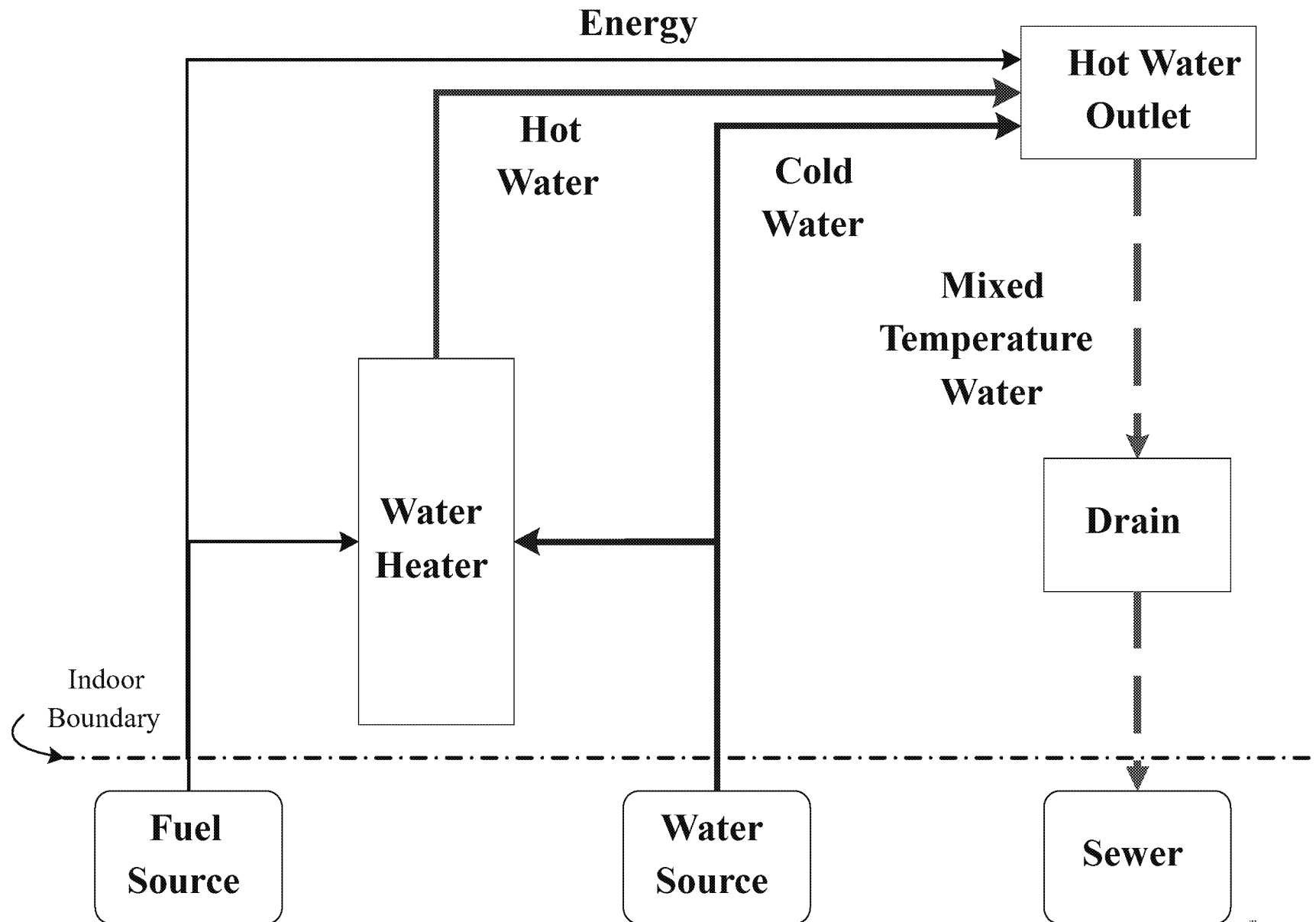
Water-using Fixture or Appliance	1980s Water Use (typical)	1990 Requirement (maximum)	EPAct 1992 Requirement (maximum)	2009 Baseline Plumbing Code (maximum)	"Green Code" Maximums (2017 CALGreen)	% Reduction in avg water use since 1980s
<b>Residential Bathroom Lavatory Faucet</b>	3.5+ gpm	2.5 gpm	2.2 gpm	2.2 gpm	1.2 gpm	66%
<b>Showerhead</b>	3.5+ gpm	3.5 gpm	2.5 gpm	2.5 gpm	1.8 gpm	49%
<b>Residential ("private") Toilet</b>	5.0+ gpf	3.5 gpf	1.6 gpf	1.6 gpf	1.28 gpf	74%
<b>Commercial ("public") Toilet</b>	5.0+ gpf	3.5 gpf	1.6 gpf	1.6 gpf	1.28 gpf	74%
<b>Urinal</b>	1.5 to 3.0+ gpf	1.5 to 3.0+ gpf	1.0 gpf	1.0 gpf	0.125 gpf	96%
<b>Commercial Lavatory Faucet</b>	3.5+ gpm	2.5 gpm	2.2 gpm	0.5 gpm	0.5 gpm	86%
<b>Food Service Pre-Rinse Spray Valve</b>	5.0+ gpm	No requirement	1.6 gpm (EPAct 2005)	No requirement	1.3 gpm	74%
<b>Residential Clothes Washing Machine</b>	51 gallons per load	No requirement	26 gallons per load (2012 std)	No requirement	12.6 gallons per load (Energy Star)	75%
<b>Residential Dishwasher</b>	14 gallons per cycle	No requirement	6.5 gallons per cycle (2012 std)	No requirement	3.5 gallons per cycle (Energy Star)	75%

***From 1980 to 2017: Reductions range from 49 to 96%***

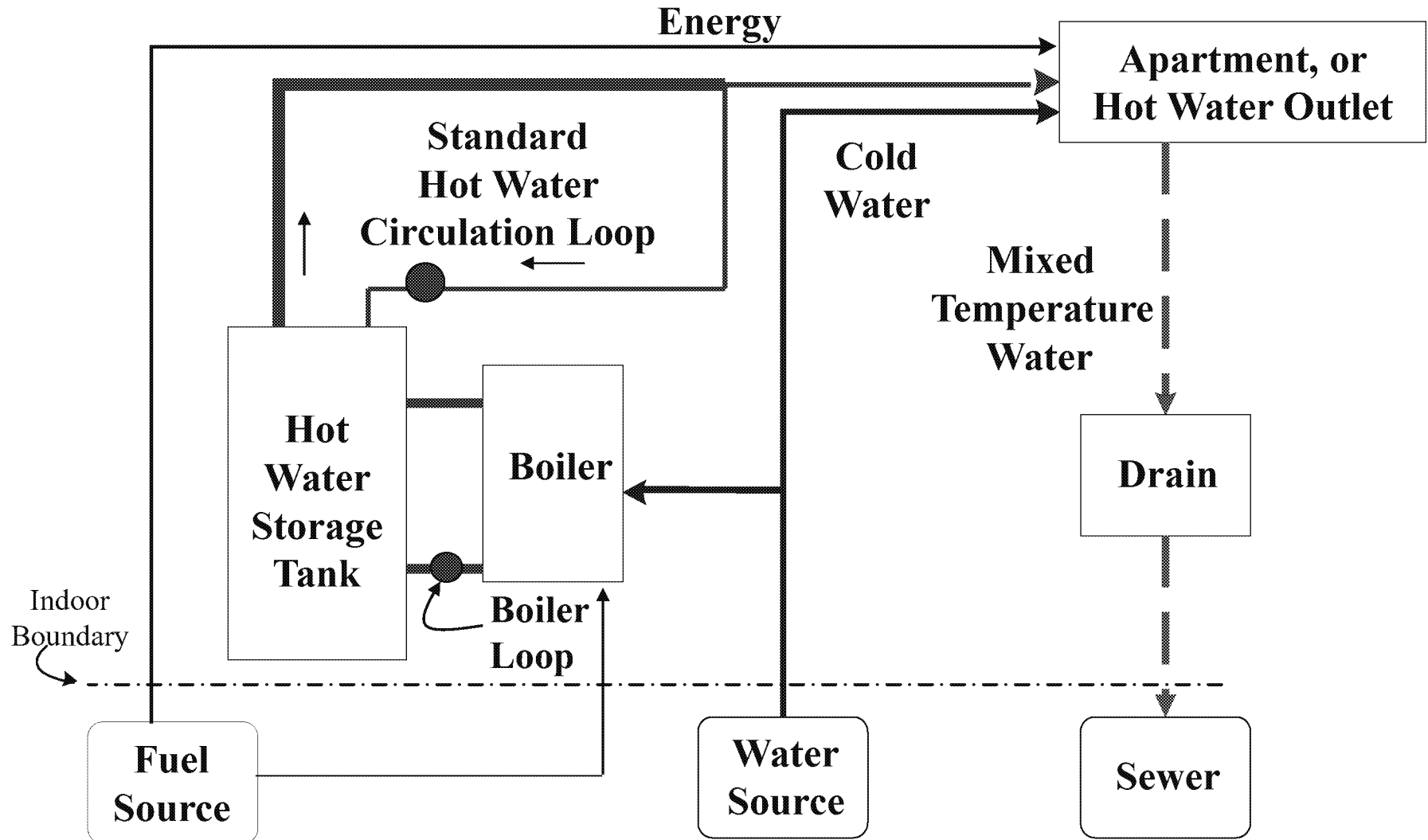
# What Are We Aiming For?

- People want:
  - The water flowing from their showers and faucets to “feel” right.
  - Their toilets to flush first time, every time.
  - Clean clothes, dishes and bodies
  - The service of hot water, as efficiently as possible.
- It does not make sense to discuss efficiency until the desired service has been provided.

# Typical “Simple” Hot Water System



# Typical Central Boiler Hot Water System



# The 2 Key Services for Hot Water...

## Hot Water Now = “Instantaneousness”

- Need hot water available before the start of each draw.
  - A tank with hot water
  - Heated pipes
- Need the source of hot water close to each fixture or appliance
- Point of Use is not about water heater size, its about location

## Never Run Out in My Shower = “Continousness”

- Need a large enough tank or a large enough burner or element
- Or, a modest amount of both

# **Where Did All the Pressure Go? (and what to do about it)**

# Let's Look at a 2<sup>nd</sup> Floor Shower

	PSI	PSI
Street Pressure	60	80
Go up 20 feet	- 9	- 9
Tub/Shower Valve	- 11	- 11
<u>Losses in the piping</u>	<u>- 20</u>	<u>- 20</u>
Total of the Pressure Losses	- 40	- 40
Residual Pressure at the shower head	20	40

Showerhead flow rates are determined at 80 psi.

For fixed orifice showerheads, the flow rate will be much less

Flow rate at 40 psi =  $0.7 * \text{Flow Rated at 80 psi}$

Flow rate at 20 psi =  $0.49 * \text{Flow Rated at 80 psi}$

Similar reductions for faucets with flow rated at 60 psi

***What can we do about it?***

# **Why Does it Take so Long for the Hot Water to Arrive? (and what to do about it)**

# Calculating Time-to-Tap and Volume-to-Hot

$$\begin{aligned}\text{Time-to-tap (seconds)} &= \text{Feet} * (\text{Ounces/foot}) * (1 \text{ gallon}/128 \\ &\quad \text{ounces}) / \text{gpm} * 1 \text{ minute}/60 \text{ seconds} \\ &= \frac{\text{Feet} * 1 \text{ oz} * 1 \text{ gallon} * 1 \text{ minute} * 60 \text{ seconds}}{1 \text{ foot} * 128 \text{ oz} * 1 \text{ gallon} * 1 \text{ minute}} \\ &= 0.46875 * \text{Feet} * \text{ounces/foot} * \text{gallons per minute}\end{aligned}$$

$$\text{Volume-to-Hot (gallons)} = \frac{\text{Feet} * 1 \text{ oz} * 1 \text{ gallon}}{1 \text{ foot} * 128 \text{ oz}}$$

**Adjustment** = Range of extra volume or time until hot is 1.5-2.5  
 $\cong 2 * \text{time in seconds based on pipe volume}$   
 $\cong 2 * \text{gallons in the pipe}$

***What can we do about it?***

# How Do We Increase Customer Satisfaction?

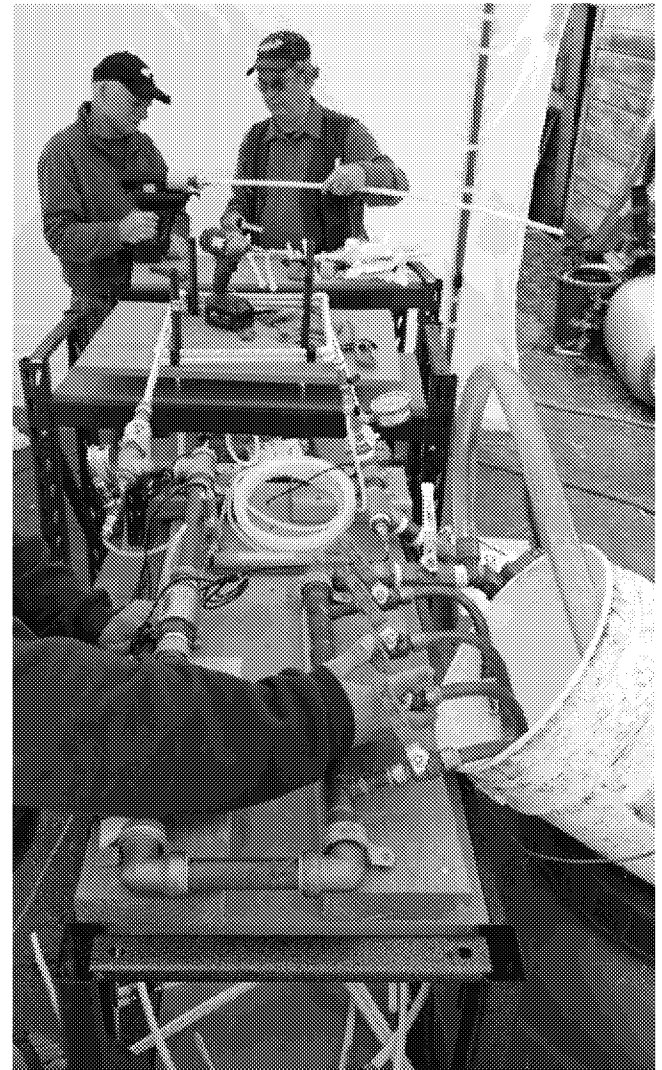
1. Reduce the Time-to-Tap
  1. Reduce the Distance from the Source to the Use
  2. Right-Size the Piping based on Modern Flow Rates and Realistic Simultaneity
2. Reduce the Pressure Drop
  1. In the Pipe and Fittings
    1. Minimize the length
    2. Minimize the number of pressure-consuming fittings
  2. In the Faucets and Shower Valves
3. Install Pressure-Independent Faucet Aerators and Showerheads

# Reduce the Pressure Drop

# Downey Lab



# Arcata Lab

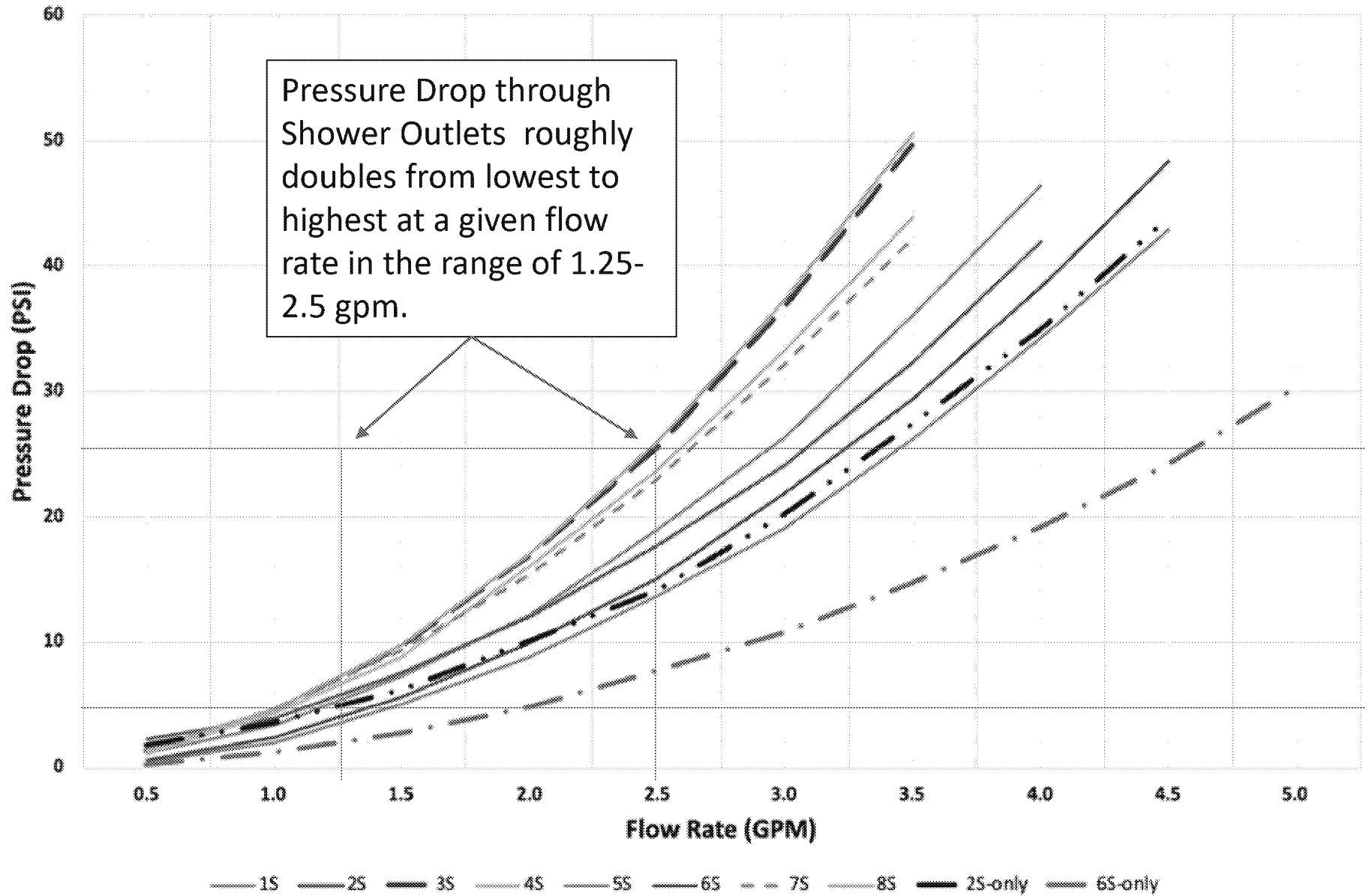


# Pressure Drop Through Tub/Shower and Shower Valves



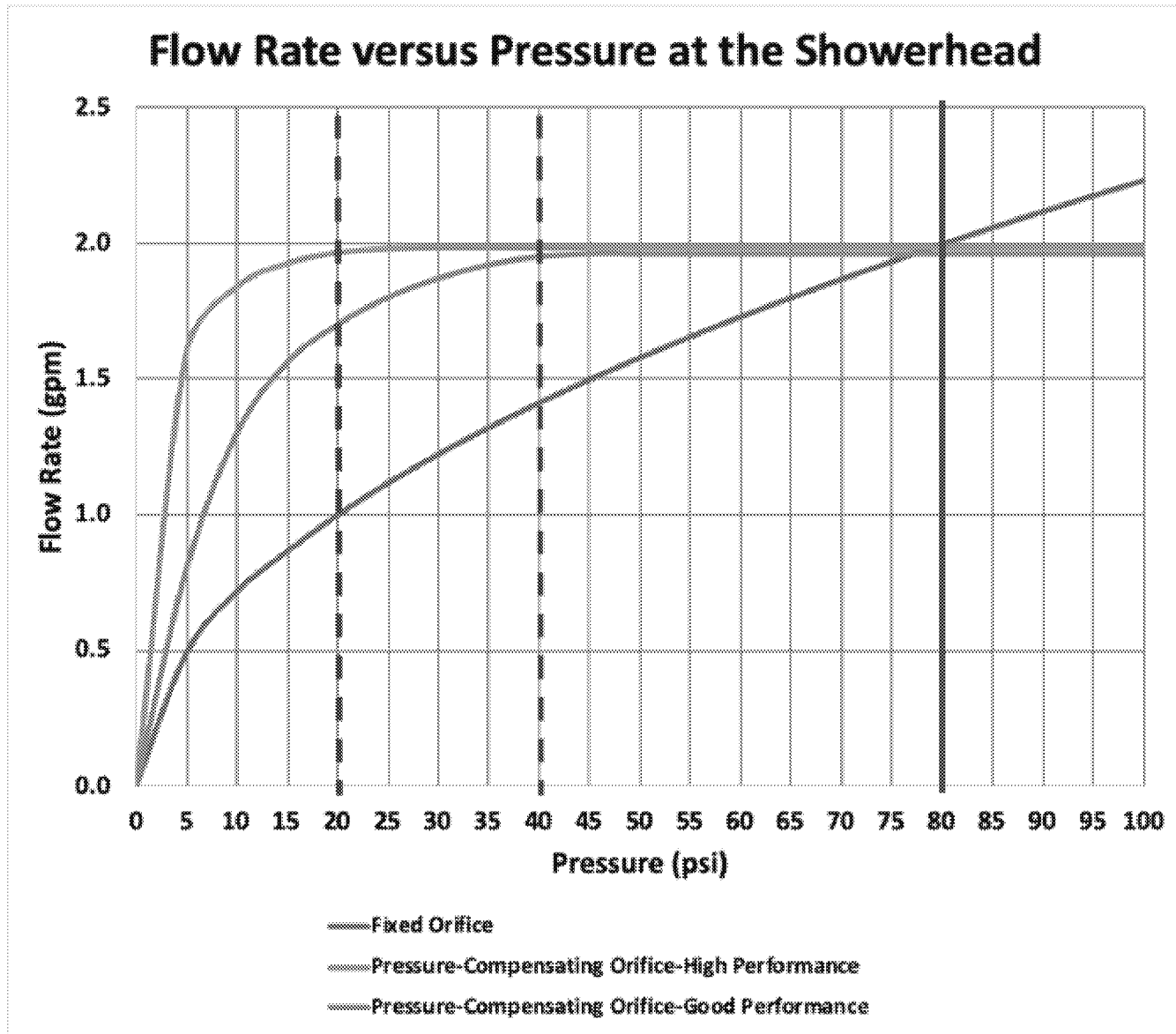
## Pressure Drop Through Valve to Shower Outlet

Pressure Drop through Shower Outlets roughly doubles from lowest to highest at a given flow rate in the range of 1.25-2.5 gpm.



# Install Pressure-Independent Faucet Aerators and Showerheads

# Which One Do You Want?

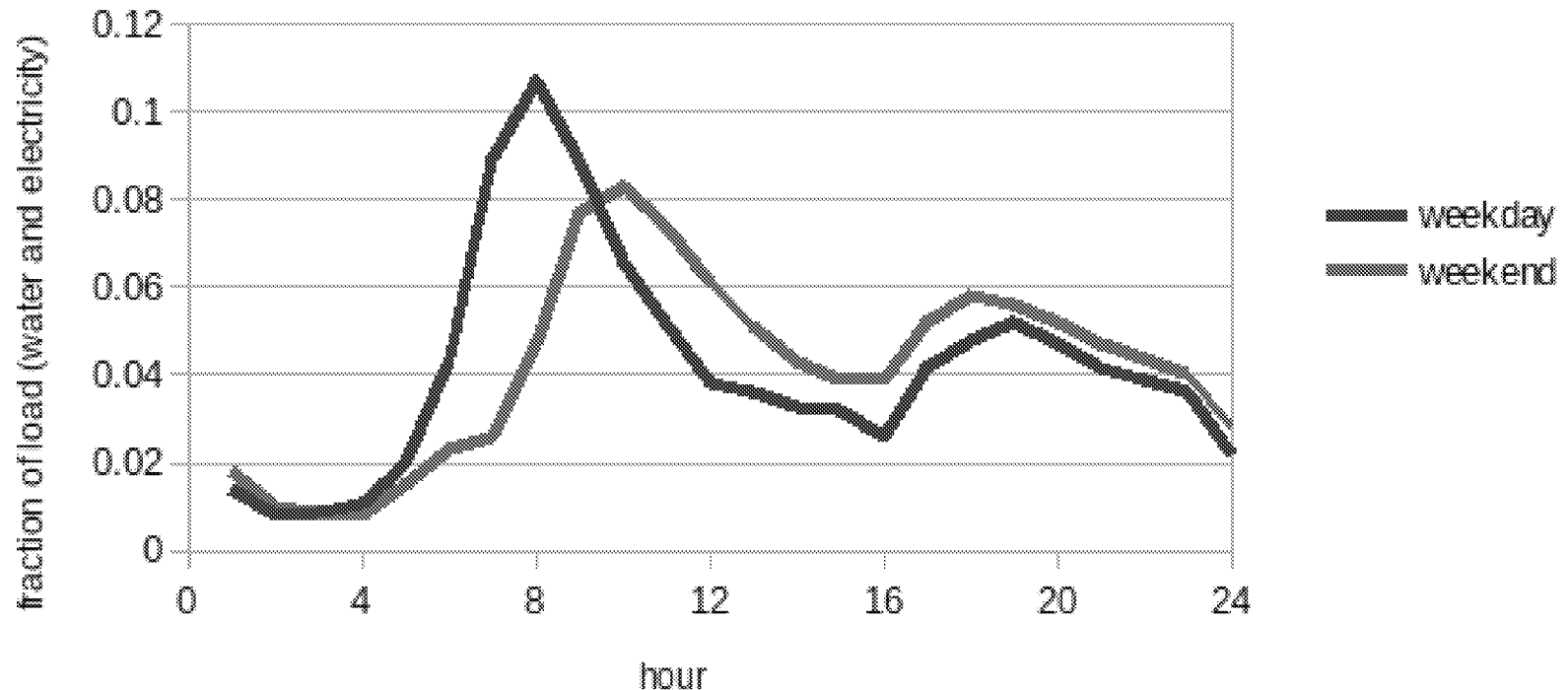


# **How Does all this Affect Water and Energy Modeling for Premise Plumbing Systems?**

# Traditional Daily Hot Water Load

Table RE-1 Hourly Water Heating Schedules

2013 Residential Alternative Calculation Method Reference Manual



# Daily Draw Patterns Considered for Analysis

Day	People	Day of Week	Daily Volume of Water (gal)	Number of Daily Draws					
				Total	Shower	Faucet	CW	DW	Bath
1	2	Wed	25.53	28	1	23	4	0	0
2	2	Sat	47.57	94	0	81	6	6	1
3	3	Thu	95.91	106	4	87	10	4	1
4	3	Thu	52.29	77	2	70	5	0	0
5	4	Mon	75.05	31	2	17	12	0	0

Percent  
Faucets

**82%**

**86%**

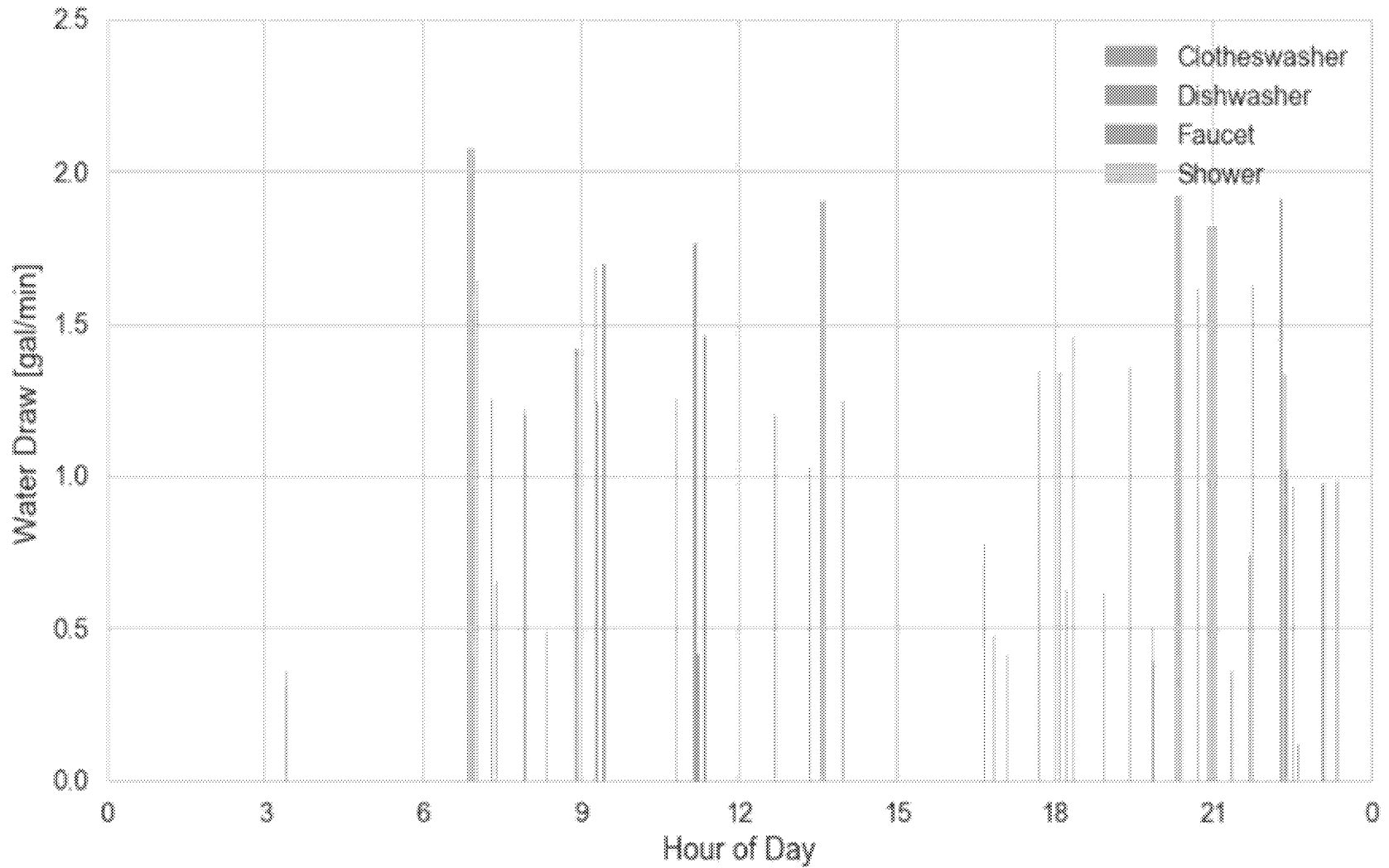
**82%**

**91%**

**55%**

CW = Clothes Washer, DW = Dishwasher,

# Actual Daily Hot Water Load



# Premise Plumbing Models – Part 1

1. Virtually nothing flushes or flows at the values used to develop the premise plumbing models. All devices were pressure-dependent (fixed orifice)
2. Hot and cold-water events are practically random, within your daily schedule, which for most of us changes daily.
  - Yes there are broad patterns, but enormous variation.
3. Distribution system performance depends on:
  - where the events happen,
  - the order of the events and
  - the time between events.
  - At the time of construction we cannot predict who the occupants will be or their schedules.
4. Systems must provide the desired service for an extremely wide variety of patterns that will change over the life of the plumbing.

# Premise Plumbing Models – Part 2

## Premise plumbing models need to be revised:

1. There are very few steady-state uses of water in premise plumbing systems.
  - The most common flow rate is zero (off). The 2<sup>nd</sup> most common is that water is flowing through 1 outlet.
  - Models need to account better for these transient conditions.
2. Pressure drop calculations need to be based on modern pipe and fittings and current and expected future flow rates.
  - Aim for pipe sizes that increase the likelihood of turbulent flow regimes in the piping a greater percentage of the time.
3. Account for the waste of water waiting for hot water to arrive, for those events that require it.
  - Both hot and premise temperature water are flowing at the same time in the hot water branch at the beginning of each hot water event.
4. Take advantage of pressure-independent faucets and showerheads
  1. Water to the people
  2. The “buckets” will fill in their own time
  3. Much less need to worry about the peak flow conditions

# Energy Models and Hot Water – Part 1

- Energy models assume that all hot water that leaves the source of hot water (water heater, circulation loop, heat traced pipe) arrives hot at the fixtures and appliances.
  - The fact that hot water use is very transient is not addressed.
  - A significant number of draws are too short in time or too small in volume to reach the fixtures. In single family dwellings this represents:
    - 50-90 percent of the daily hot water events.
  - These small events do not appear to waste water, but the energy gets stranded in the piping. This represents:
    - 15-25 percent of the daily hot water energy use.
  - At present, the best way to comply with Title-24 hot water energy budget is to not deliver hot water

# Energy Models and Hot Water – Part 2

## Energy models need to be revised:

1. Establish an equal level of hot water service to compare the energy performance of the alternatives.
  1. For hot water distribution, service means time-to-tap or volume-until-hot
  2. Establish a minimum percentage of daily events that must arrive as hot water, say 105F or hotter.
  3. Predict the system performance with transient events and for any pattern of use.
  4. Account for the waste of water waiting for hot water to arrive, for those events that require it.

**Given human nature,  
it is our job  
to provide the infrastructure  
that supports efficient behaviors.**

# Questions?

***Thank you!***

# **Vision for an EPANET for Premise Plumbing Modeling**

Walter M. Grayman  
Consulting Engineer  
Oakland, CA

Premise Plumbing Modeling Webinar  
April 22, 2020

# Purpose of this Presentation

- Applicability of a specialized EPANET (or other packages) for modeling premise plumbing.
- What changes may be needed in existing software when modeling premise plumbing?
- Should a special-purpose software package for modeling premise plumbing be built?
- Would anyone use such a package?
- What should such a software tool look like?

# Modifications in EPANET for Premise Plumbing

- **ENGINE:** Modifications in the way that EPANET simulates the hydraulic and water quality behavior
- **INTERFACE:** Modifications in the interface and integration aspects of the software.

# Engine Modifications to Support Premise Plumbing Modeling

- Demand representation
- Hydraulics: Dispersion, laminar flow and operation of premise plumbing fixtures
- Water quality components

# Demand Representation

- EPANET supports fixed patterns and pressure-dependent demands (new feature)
- Premise plumbing modeling additionally requires:
  - Stochastic demands
  - Very fine time-scale patterns
  - Hybrid models – volume and pressure dependent representation (e.g., a washing machine that fills to a fixed volume at a rate dependent on pressure)

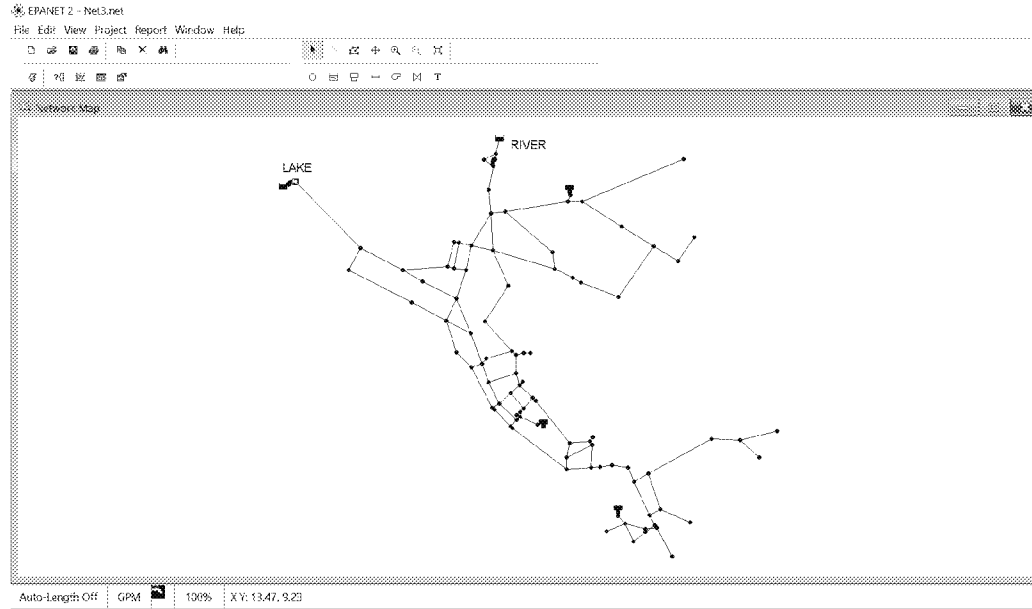
# Hydraulics

- Laminar flow: low velocity conditions
- Dispersion: non advective transport
- Highly intermittent flow
- Operation of premise components (e.g., water heater)

# Water Quality Representation

- Expanded multi-species modeling of:
  - Temperature
  - Legionella, viruses, bacteria
  - Lead, copper, corrosion
  - Other water quality parameters
- Additional research and understanding needed

# Interface Modifications

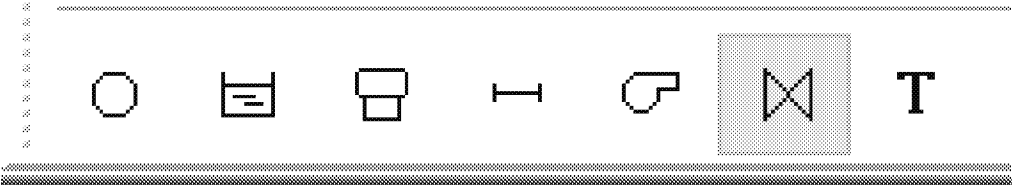


***A standard EPANET GUI. What needs to change?***

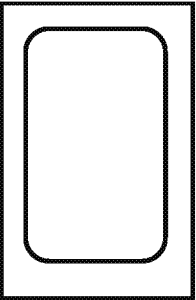
- Components needed in a premise plumbing model
- Display: 3-D representation of premise plumbing
- Integration with CAD/BIM software

# Palette of Components

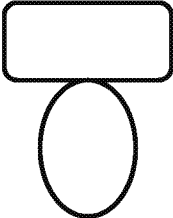
Standard  
symbols



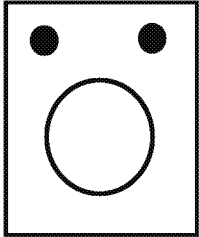
## Premise Plumbing Symbols



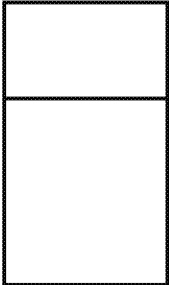
BATHTUB



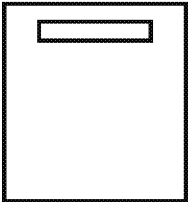
TOILET




WASHING  
MACHINE




REFRIGERATOR




DISHWASHER



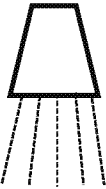
HOT WATER  
HEATER




SINK




METER




SHOWER



FAUCET



COLD WATER PIPE



HOT WATER PIPE

... and others?

# Display and Integration

We need to reach out to the BIM (Building Information Modeling) and CAD communities to:

- what is available?
- what is needed?
- develop a plan to support premise plumbing modeling

# Potential Applications for EPANET-PPM

- Assist in design of PP
- Improve operation of PP
- Investigate vulnerability of PP to contamination
- Understand the water quality processes in PP
- ..... and many more

# Some Points for Discussion

- Is there sufficient interest?
- Commercial or public software or hybrid?
- Research tool or application package?
- Who needs to be involved in decisions?

# Participant Survey Results

Steve Buchberger (1 of 6)

- 1-pg survey with 4 questions emailed to 40+ people January 2, 2020.
  - **Q1:** What are the most important **research and development needs** to support computer modeling of premise plumbing systems?
  - **Q2:** In what areas do you see that premise plumbing models could be **usefully applied** in the future?
  - **Q3:** What are the **main challenges** in adopting premise plumbing models in practice?
  - **Q4:** Please add any **additional thoughts**.
- 219 ideas on 22 responses summarized on next 5 slides



# Participant Survey Results

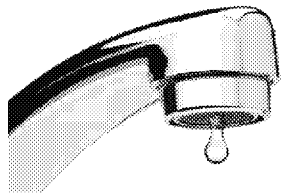
(2 of 6)

No	Network Feature	Water Distribution System	Premise Plumbing System
1	Responsibility	Water utility	Private owner
2	Topology	Looped network w some stubs	Branching pipes with many stubs
3	Pipe placement	Below ground (in the dirt)	Above ground (in the walls)
4	Flow regime	Mainly turbulent	Mixture of laminar, critical, turbulent
5	Demands	Continuous random stream	Intermittent random pulses
6	Stagnation	Relatively rare	Very common
7	Design flow	Fire demand	99 <sup>th</sup> percentile of peak period
8	Temperature	Ambient conditions	Hot and cold water systems
9	Fixtures	Industry standards	Assortment of appliances (“gizmos”)

# Participant Survey Results

(3 of 6)

- **Q1:** What are the most important **research and development needs** to support computer modeling of premise plumbing systems?
  - Understand water quality dynamics in PPS
  - Characterize and model water demands in PPS
  - Adapt/develop a network-type model to PPS

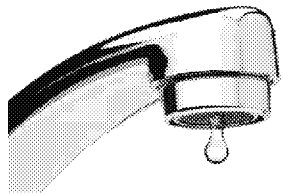


## 80 needs identified



(4 of 6)

- **Q2: In what areas do you see that premise plumbing models could be usefully applied in the future?**
  - Tool to inform **building design** (link to MEP-BIM software)
    - optimize pipe size and layouts, minimize cost, energy use
    - prevent backflow, cross-connections other code violations
  - Tool to inform **building operation and maintenance**
    - hot spots for sample collection / water age / stagnation
    - flushing programs / vulnerability assessments



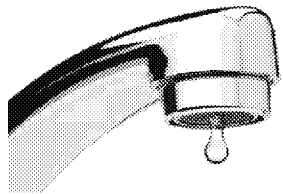
## 64 applications identified



# Participant Survey Results

(5 of 6)

- **Q3:** What are the **main challenges** in adopting premise plumbing models in practice?
  - Acceptance by the plumbing engineering community
  - CO\$T, CO\$T, CO\$T (acquire, use, implement.....\$\$\$)
  - Difficulty in creating and sustaining a reliable user-friendly product (conceptualize, code, calibrate, validate, apply)



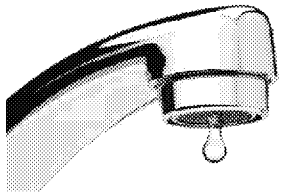
## 60 challenges identified



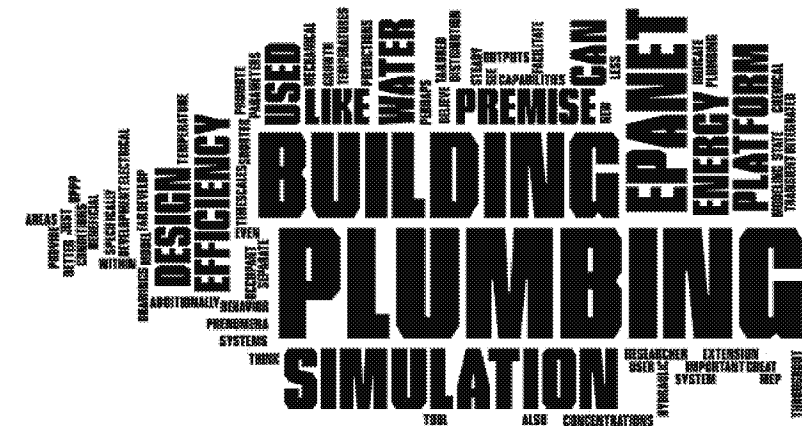
# Participant Survey Results

(6 of 6)

- **Q4: Please add any additional thoughts**
  - Great opportunity for collaboration among agencies and across disciplines
  - Efforts should lead to journal paper(s) and research proposals
  - Produce state-of-the-science material for engineering curriculum
  - Important to connect with the “building energy simulation” crowd



15 added thoughts (W.O.E.)  
“Words of Encouragement”



# Feedback and Q/A

# What's Next?